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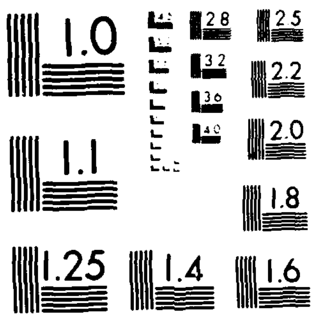
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# NAVAL POSTGRADUATE SCHOOL
## Monterey, California

# THESIS

A SMALL-UNIT AMPHIBIOUS OPERATION COMBAT MODEL

by

James Madison Crites

March 1983

Thesis Advisor: James G. Taylor

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# A Small-Unit Amphibious Operation Combat Model

by

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Captain, United States Marine Corps
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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

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## ABSTRACT

This thesis develops a Lanchester-type force-on-force combat model simulating small-unit amphibious operations. The model commences with a ship-to-shore assault of aggressor forces mounted onboard Landing Vehicle Assault craft moving against a defensive force ashore. Once the ship-to-shore phase of combat is completed, the model continues to simulate land combat further inland between the assaulting aggressor forces and other defensive forces occupying key terrain.

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# I. INTRODUCTION

## A. OVERVIEW

This thesis develops a Lanchester-type force-on-force combat model simulating small-unit amphibious operations. The model commences with a ship-to-shore assault of aggressor forces (e.g., a U.S. Marine Infantry Battalion), mounted onboard Landing Vehicle Assault craft (LVA) moving against a defensive force ashore located in fixed positions along the coast the aggressor force is attempting to occupy. Once the ship-to-shore phase of combat is completed, the model continues to simulate land combat further inland between the assaulting aggressor forces and other defensive forces occupying key terrain.

The main thrust of the thesis is to alleviate some of the problems associated with the inherent abstractness of Lanchester-type combat models (see [Ref. 1]), and specifically to integrate and enhance work done in previous models, to develop "user-friendly" enhancements, and more thorough documentation of algorithms to provide a model which would be more easily understood and utilized by students of combat modeling.

## B. BACKGROUND AND GENERAL MODEL

### 1. Overview

The small-unit amphibious operation combat model presented in this thesis is the result of the integration and enhancement of two independent combat models. The first model is a ship-to-shore combat model which models a ship-to-shore assault conducted by landing vehicle assault craft against fixed enemy positions ashore. The second model

is a land combat model which models a land assault conducted by LVA forces on a beach, against fixed enemy positions further inland.

2. Original Ship-to-Shore Combat Model

The ship-to-shore combat model used as a basis for this thesis was presented in a thesis by David L. Chadwick [Ref. 2]. It modeled the amphibious assault of five waves of LVA against a defensive force composed of tanks and antitank guided missiles (ATGM) in fixed positions ashore. Attrition was modeled using Lanchester area-fire and aimed-fire equations. The purpose of developing such a model was to determine the optimal design characteristics of LVA in an amphibious assault for a given combat scenario. The optimal design of an LVA was considered to be that design which produced the lowest level of LVA attrition for the given combat scenario.

3. Original Land Combat Model

The land combat model used as a basis for this thesis was developed in Joseph Smoler's thesis [Ref. 3]. It modeled land combat conducted by three aggressor force units utilizing tanks assaulting three defensive force units armed with Tube-Launched, Optical-Guided, Wire-Controlled missiles (TOW's) in fixed positions. The location of the land combat was the Fulda Gap region in West Germany. Attrition was modeled using Lanchester aimed-fire equations. The purpose of Smoler's thesis was to develop a basic small-unit land combat model for determining optimal defensive unit locations for a given combat scenario. The optimal locations of the defensive units were considered to be those locations which provided the lowest level of attrition of the defensive units for the given combat scenario.

### 4. The Enhanced Land Combat Model

An enhanced version of Smoler's land combat model was developed by Glenn Mills in his thesis [Ref. 4]. The enhancements developed by Mills added flexibility to Smoler's land combat model by providing user selected options which could be employed depending upon the abilities and desires of the model's user. The enhancements included the option of altering the aggressor force's attack routes enabling the user to study not only the optimal defensive unit locations, but the optimal aggressor force attack routes for the given defensive unit locations as well.

A second enhancement was the option of selecting a stochastic attrition-rate coefficient. This introduced the element of randomness into the model's attrition algorithm providing a more realistic approach to modeling a unit's fighting effectiveness.

The third enhancement is the option of providing alternate defensive positions so that the defensive units could move to more defensible terrain once their original positions had become untenable.

### 5. The Original Small-Unit Amphibious Warfare Model

The original small-unit amphibious warfare model used as a basis for this thesis was developed by Soon Dae Park in his thesis [Ref. 5]. Park's model attempted to conceptualize the flow of events of an amphibious assault by first running the ship-to-shore model, followed immediately by running the land combat model. The analysis of this model as a class project served as the catalyst for the development of the small-unit amphibious operation combat model presented in this thesis.

6. The Analysis of Park's Model

The class project conducted by Clay Grubb, Robert Larson, and this author had as its purpose the analysis of Soon Dae Park's small-unit amphibious operation combat model. The results of the analysis revealed the value of Park's thesis in providing a general scheme of events for the modeling of small-unit amphibious operations. The results also identified some enhancements that could be applied to his conceptualized model that would integrate the ship-to-shore and land combat models into a singular small-unit amphibious operation combat model. The development and application of these enhancements to Park's model served as the foundation for this thesis, and the development of the model presented.

## C. MAJOR GOAL AND OBJECTIVES OF THE THESIS

### 1. Major Goal of the Thesis

The overall goal of the thesis is the development of a small-unit amphibious operation combat model. It will be based on the integration and enhancement of the two combat models discussed in the previous section of this chapter. There are three underlying objectives of the thesis which will guide the development of the model toward the accomplishment of this goal.

### 2. Objectives of the Thesis

#### a. Integration of Independent Combat Models

The first objective in the development of the model was to integrate two initially independent combat models into a singular continuous flow combat model. This was accomplished by first allowing force levels at the completion of the ship-to-shore phase of combat to be used as the initial force levels in the land phase of combat.

Secondly, it was recognized that four combat modelers contributed to the resulting model presented by Park in his thesis. As such, four individualized FORTRAN coding techniques were reformulated into one style to provide a more tractible small-unit amphibious operation combat model.

b. User-Friendly Input-Data and Output Structure

The second objective of the thesis was to provide a user-friendly combat model. It is a major contention of this thesis that combat modelers have not adhered closely to this principle when providing combat models for the United States military. Furthermore, it is believed that the lack of concern given to this approach of combat modeling is a major reason for the less than unanimous reception that combat models have received by the United States military as tools for training its commanders and staffs. Therefore, the model presented in this thesis was designed and documented with the user's capabilities and needs in mind as opposed to those of the programmer.

c. Student-Oriented Combat Model

The third objective of the thesis was to provide the student of combat modeling with a combat model which was easily understood and studied. As a result, the model presented in this thesis was designed with a low level of complexity to allow the student with little or no experience in combat modeling to understand more easily the combat modeling theory and its application.

## II. MODEL ENHANCEMENTS

### A. OVERVIEW

This thesis had as its goal the development of a small-unit amphibious operation combat model. Guided by the three objectives discussed in Chapter One, five modeling enhancements were applied to the two original combat models serving as the foundation for the resulting small-unit amphibious operation combat model presented in this thesis. The enhancements provide for the proper integration of the ship-to-shore and land combat models. In addition, they have contributed to the development of a more user-friendly combat model which can be used to assist combat modeling students in their understanding the theory of combat modeling and its application.

### B. INTEGRATION OF SHIP-TO-SHORE AND LAND COMBAT MODELS

The intent of the model presented here is to view the amphibious assault as a continuous process made up of two phases of combat (ship-to-shore, and land combat) where the land combat phase is dependent upon the outcome of the ship-to-shore combat phase of the model.

Implementation of this enhancement called for the creation of a new variable, Total Landing Force Ashore (TLF), which would accumulate the surviving landing force of each assault wave as it reached the beach. This total landing force ashore would than be redistributed into three main assault units for the land combat phase of the model. The rationale for the redistribution of forces is based on realistic

military doctrine which is to maintain a well-balanced force when the strength and location of the enemy is unknown to the assaulting forces (as is assumed in the model).

Since the manner in which defender force levels are determined by the ship-to-shore and land combat models appears to be quite realistic, the defending force level as modeled by Soon Dae Park was used as input to the land combat phase. In particular, if the aggressor force had been successful in routing the defending forces situated on the beach, defending forces situated further inland naturally would be impelled to defend the remaining terrain still in their possession. It should be noted that the size of these defending forces further inland is an option of the user which in itself can be varied for analysis of variant battle scenarios.

C. AGGRESSOR FORCE ATTRITION--SHIP-TO-SHORE PHASE

Attrition in Lanchester-type combat modeling is based upon the expected percentage of the original force remaining at a given point in time. The expected percentage of forces remaining then can be restated in terms of a real number to represent the expected number of forces remaining. This method of computing reduced force levels is considered to be quite appropriate when modeling land combat, and was implemented by Chadwick in his ship-to-shore combat model to simulate LVA attrition. However, use of Lanchester equations to model such vehicular attrition of a vehicle at sea was determined to be inappropriate. Where it is a reasonable assumption that a disabled vehicle on land still can contribute something toward the final outcome of the battle if any of its weapons systems or onboard troops survive,

an LVA that is disabled at sea is of no use to the amphibious assault and subsequent land combat phase. The LVA will be recovered, and on-board troops brought to the landing site after the assault has taken place.

Chadwick was not concerned with this distinction due to his model's purpose of modeling LVA attrition in terms of ship-to-shore movement only. Therefore, he simply utilized Lanchester equations in modeling LVA attrition resulting in fractionalized losses of assaulting LVA's. However, if a *ship-to-shore combat model* is to be properly integrated with a land combat model, only whole numbers of LVA's ashore should be used as input. Hence, an enhancement was made to the model.

The approach was to find the integer value of the number of surviving LVA's in each assault wave, and then sum these values resulting in the total landing force ashore (TLF). The fractional portion remaining was considered to be those LVA's disabled at sea and unable to participate in the land combat phase of the operation.

## D. STOCHASTIC ATTRITION-RATE COEFFICIENT MODIFICATION

Mill's land combat model allowed the user the option of selecting either deterministic or stochastic attrition-rate coefficients to be used in assessing the attrition of opposing forces. The justification for utilizing stochastic attrition-rate coefficients to model force-on-force attrition rates was based upon the assumption that the attrition-rate coefficient is a random quantity measuring a unit's fighting ability, and can be estimated before any given battle.

This can be illustrated by considering the expected value of a random variable. For example, assume a probability distribution is

selected for the random variable such that the expected value of the random variable is equal to the deterministic attrition-rate coefficient set for all units. When a random sample is taken from this distribution, the individual values assigned the random variable will serve as individual unit attrition-rate coefficients, where the sample mean will serve as the overall force attrition-rate coefficient. The result is that the overall force attrition-rate is equal to the sample mean, which is approximately equal to the population mean of the random variable. Recalling that this population was selected with a mean that equalled the deterministic attrition-rate coefficient, units now have their own individual attrition-rate coefficients, while the force attrition-rate coefficient has remained close to the intended value of the deterministic attrition-rate coefficient. This is more realistic than the deterministic option since each unit would be expected to have a different level of effectiveness, which necessarily would imply different attrition rates while maintaining one overall force level attrition rate.

The attrition-rate coefficient, $A_{ij}$, is used as the measure of the rate a firer in Unit i attrits a target in Unit j. This has been likened to the fighting effectiveness of a particular Unit i. Obviously, this is a variable quantity influenced by a myriad of factors to include esprit de corps, past history of success or failure, prior exposure to combat, weather, quality of leadership, etc. The intent of such a basic model as this is to attempt to capture the overall effect of these factors by developing a distribution of a unit's initial fighting capabilities (specifically, to develop a distribution of $A_{ij}$'s for the unit).

Mills proposed a distribution based upon a quadradic function which would produce a symmetric distribution with a mean value of approximately 0.55. This distribution restricted a unit's maximum effectiveness to only 80 percent of its maximum capable effectiveness level. It also implied that the average unit in combat will only perform at 55 percent of its maximum effectiveness level at any given time.

A more plausible way of assigning a distribution to the $A_{ij}$'s might be a truncated Normal Distribution limited to values between 0.00 and 1.00. However, this approach would leave little flexibility in terms of modeling variant scenarios since the opposing forces always would have attrition-rate coefficients associated with that particular distribution whenever the stochastic option was selected. This restriction is due to the programming constraints encountered in attempting to implement variant truncated Normal Distributions in the model. Therefore, a Beta Distribution was selected for use in the model.

The natural range of the Beta Distribution is from 0.00 to 1.00 thereby alleviating the burden of constructing a truncated distribution. Furthermore, its two scaling parameters, P and Q, can be selected readily and input by the user to construct virtually any variant of the Beta Distribution so desired. The specific values selected for P and Q would parameterize the distribution of the $A_{ij}$'s according to the user's particular combat scenario without the burden of reprogramming the distribution on each successive run of the model.

The density function for the Beta Distribution is as follows:

$$f(x) = X^{P-1}(1-X)^{Q-1} \quad \text{for } 0.0 \leq x \leq 1.0$$

$$\text{with } \mu_x = \frac{P}{P+Q}$$

Therefore, a P=21 and Q=7 would yield a distribution of $A_{ij}$'s with a mean of 0.75. This says that a unit with an $A_{ij}$ of 0.75 is operating at 75 percent of its potential effectiveness. Whereas, a P=7 and Q=21 would yield a distribution of $A_{ij}$'s with a mean of 0.25, indicating that a unit is operating at 25 percent of its potential effectiveness.

To illustrate the flexibility of this approach in determining stochastic attrition-rate coefficients, Figure 2-1 is provided displaying the distribution of $A_{ij}$'s that would be obtained when the user alters the parameters of the Beta Distribution. The user now can model a strong elite force using, for example, parameter values P=21, Q=7, or model a weak and poorly lead force using parameter values P=7 and Q=21, depending upon the particular battle scenario the user is analyzing.

While the Beta Distribution used in this thesis is different than the Quadradic Distribution used by Glenn Mills, the implementation of this distribution for the attrition-rate coefficients is exactly the same as originally modeled. Since it was assumed earlier that the fighting effectiveness of each unit is a random quantity prior to a given battle, it is only necessary to obtain a realization of the random variable for each unit prior to the initialization of the battle. This realization, $A^o_{ij}$, is determined by the user-supplied inputs P and Q, and subsequent calls to a Beta Distribution Random Deviate Generator [Ref. 6]. Therefore, an attrition-rate coefficient is computed for each unit using the following equation:

$$A_{ij} = \begin{cases} A^o_{ij} \times (1 - r/r_e)^2 & \text{for } 0 \leqq r \leqq r_e \\ 0 & \text{for } r_e \leqq r \end{cases}$$

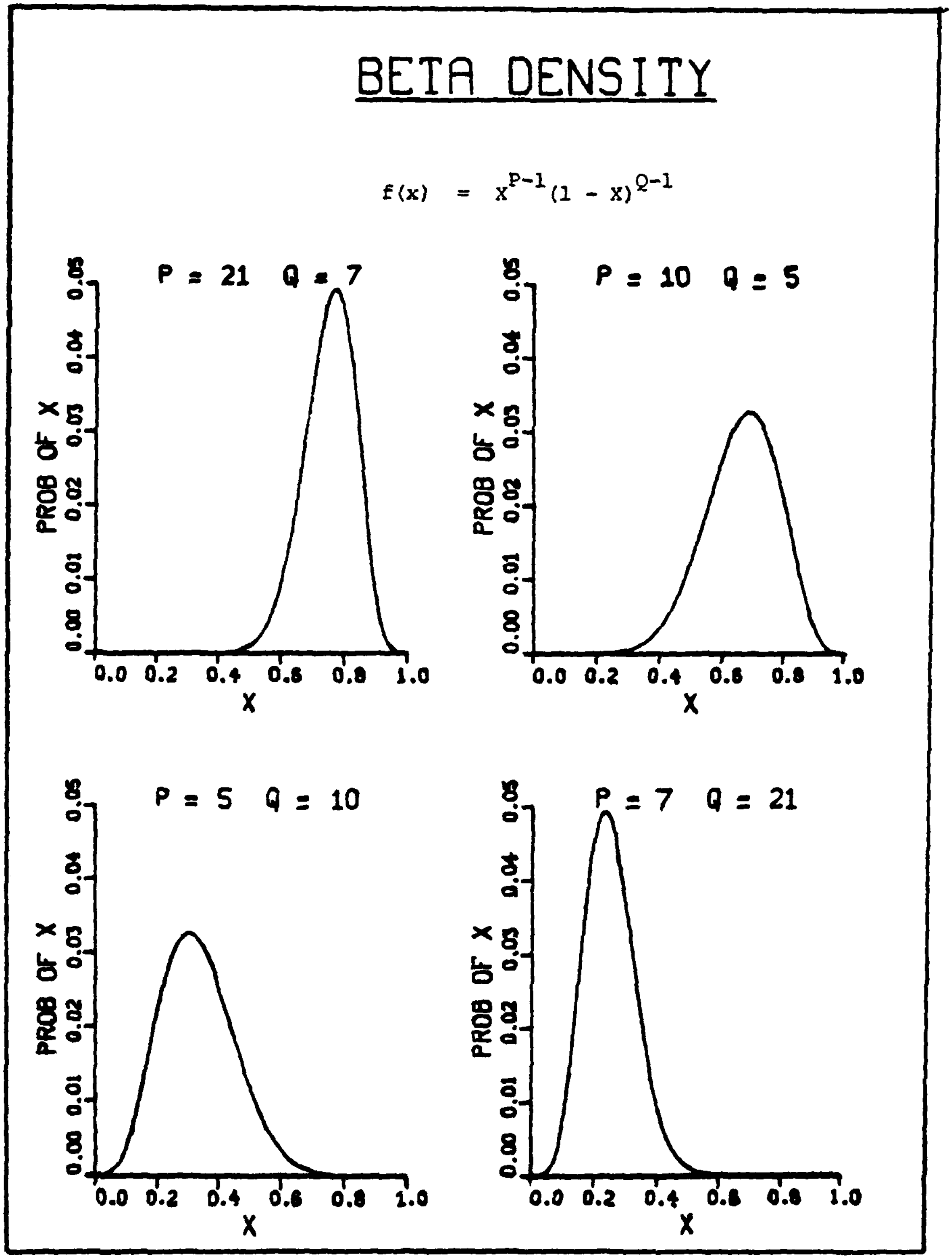



Figure 2-1. Beta Density

Where: $A^o_{ij}$ = Realization of unit's fighting effectiveness

$r$ = Current range between firer and target

$r_e$ = Maximum effective range of a firer's weapon

This function was utilized because it is a function of both range and $A^o_{ij}$ thus creating a different attrition-rate curve for each unit, depending on that unit's effectiveness level prior to the battle. A graphic illustration of an attrition-rate coefficient curve for an $A^o_{ij}$ equal to a mean of 0.75 from the Beta Distribution where P=21 and Q=7, and the maximum effective range $r_e$, of 3000 meters would look like Figure 2-2.

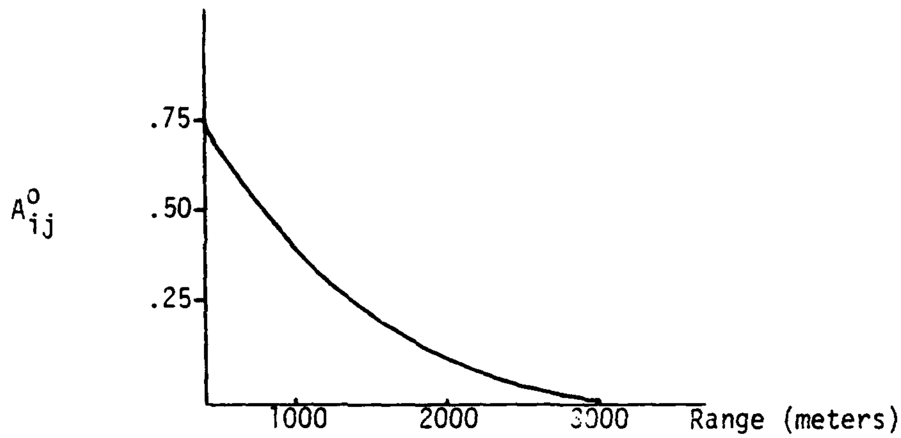



Figure 2-2. Attrition-Rate Coefficient Curve for $A^o_{ij}$ = 0.75 and $r_e$ = 3000m

To illustrate the effect that this stochastic attrition option has on the outcome of the model, two runs of the model were made using this option, while varying the Beta Distribution parameter values for both forces on each run. All other characteristics of both forces were left unaltered. In the first run, the aggressor forces were modeled to operate at 75 percent of their potential effectiveness, and the defending

forces were modeled to operate at 25 percent of their potential effectiveness. The battle outcome, as listed in Table 2-1, indicates that the aggressor forces won the battle. In the second run, the potential effectiveness of the opposing forces was reversed. The aggressor forces were now modeled to operate at 25 percent of their potential effectiveness, and the defending forces were modeled to operate at 75 percent of their potential effectiveness. The battle outcome, as listed in Table 2-1, indicates that the battle was terminated due to the opposing forces being too close. The aggressor forces were unable to overrun the defending forces, as was the case in the first run, which was due solely to the change in the potential fighting effectiveness of the opposing forces.

A change in the battle outcome was expected; however, to what degree that change would be was unknown. The fact that the defender forces were unable to win the battle on the second run, while having a much higher level of effectiveness, indicates that other characteristics of the opposing forces were also playing an important role in the battle (e.g., types of weapons employed, original force levels, speed of attack, etc.).

Through the use of the stochastic attrition option, the user now has the capability of studying one more facet of combat (i.e., potential fighting effectiveness), and can analyze to what degree different fighting effectiveness levels will have on final battle outcome.

## E. USER-FRIENDLY I/O STRUCTURE

A significant and important part of writing a computer program for a combat model is to provide for the input and output of data to and from the program. It is my belief that one of the major factors

Table 2-1. Comparison of Runs while Varying the Stochastic Attrition-Rate Parameters

| Run No. | AGGRESSOR FORCES Percent Effectiveness | AGGRESSOR FORCES Resulting Force Level | | | DEFENDER FORCES Percent Effectiveness | DEFENDER FORCES Resulting Force Level | | | Time (sec) | Battle Outcome |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Unit 1 | Unit 2 | Unit 3 | | Unit 1 | Unit 2 | Unit 3 | | |
| 1 | 75 | 0.0 | 4.8 | 17.9 | 25 | 0.0 | 0.0 | 0.0 | 745 | A WINS |
| 2 | 25 | 0.0 | 0.0 | 18.0 | 75 | 0.0 | 5.0 | 0.0 | 865 | TOO CLOSE |

contributing to the lukewarm reception, in general, that combat models have received by the United States military is due, in part, to the poorly designed input-data and output structure of the combat models. The primary user of those models, the military commander, normally finds it difficult to decipher the myriad of input-data requirements, or the voluminous output from combat models that supposedly were designed for the commander's use. It is a contention of this thesis that if more attention was given to the development of user-friendly input-data/output requirements, that more interest would be generated toward the use of such models in training military commanders. Therefore, an enhancement was made to the input-data and output requirements of the model to demonstrate a method of alleviating this problem.

1. User-Friendly Input Structure

A readymade input data file was provided with the model to serve as a guide for entering all of the required data in the correct format required by the model (see Appendix C). Each variable requiring input for the model has been listed in the sample input file with sufficient space provided for ensuring that data is entered in the correct format. This file, therefore, provides the unfamiliar user of the model with the opportunity to utilize the model with only a limited knowledge of the model's algorithm and input requirements. This type of user-oriented input requirement will alleviate some of the apprehension that an unfamiliar user of the program might have, and might actually act as a catalyst in increasing the amount of use the model receives.

2. User-Friendly Output Structure

Indecipherable output, or too much output from a model, can be just as much of a deterrent to a model's use as complex input requirements can be. This point was brought out by Ye S. Venttsal in her discussion of good combat models:

> It is advisable in such "training" modeling of combat actions that the commander receive information from the computer not in the form of mean characteristics averaged over a set of realizations, but rather in the form of only one specific realization, on the basis of which a decision is in fact made. [Ref. 7]

To paraphrase Venttsal, the combat model output must be clear, concise, and identifiable to the military commander. Furthermore, it must answer the questions that were originally asked by the user--specifically, who won and why?

The model output was therefore restructured to provide a concise listing of what input parameters were entered into the program for processing, and a concise and understandable output summary of what occurred throughout the battle (see Appendix F). Additionally, a new feature was introduced into the model which gives the user the option of viewing either a detailed time-step battle summary, or just a final battle summary of what occurred in the running of the model.

## F. DOCUMENTATION AND PROGRAM FORMAT

Two of the objectives of the model presented in this thesis were first to serve as an example of the way in which combat models should be designed to be user-friendly to ensure their acceptance and use in training military commanders; and secondly, to serve as a model for combat-modeling students so that they might acquire a better understanding of how combat models ought to be programmed into a computer.

It already has been discussed how the user-friendly I/O structure assists the user of the model. However, proper structuring of programs for readability and good documentation is equally necessary to ensure readability and understanding by students and analysts.

The FORTRAN program presented in this thesis which integrated and enhanced the ship-to-shore and land combat models is an amalgamation of subroutines originally written by different people, with their own unique style of programming. The interweaving of these four styles of programming throughout the program seriously detracted from the smooth flow of program structure and readability desired when analyzing the computer program. Therefore, an enhancement was made to the model: the program was restructured so that it would follow one basic style of programming (see Appendix B). New labeling and structuring of formatted statements and nested FORTRAN functions were provided to make the computer program more readable. This restructuring should assist the student in understanding the program flow, and provide an incentive to those interested students to develop future enhancements to the model.

In addition to developing one style of programming, more detailed documentation of variable definitions and descriptions of program flow were added to the program. The purpose of this documentation was to have the program serve as a reference to itself in order that the reader would not be forced to refer to various manuals outside of the program each time an explanation of the functioning of a particular aspect of the program is desired.

# III. CURRENT MODEL DESIGN

## A. OVERVIEW

The small-unit amphibious operation combat model presented in this thesis consists of the integration and enhancement of a ship-to-shore combat submodel, and a land combat submodel. Both of the original submodels were similar in design, basing force attrition on Lanchester-type expected-value equations. As presented earlier, enhancements to both submodels reduced the differences in design of these submodels, molding them into what may be called a small-unit amphibious operation combat model. Figure 3-1 provides the scheme for the sequence and general flow of events in the overall model.

It should be noted that although the ship-to-shore and land combat models are quite similar, they still have their own unique characteristics in modeling certain events that take place throughout the battle. Therefore, in discussing the model as a whole, the two phases of the battle will be addressed separately, and those events which are of particular interest in each phase of combat will be elaborated on in order that the reader might acquire an overall appreciation of the contributions each submodel makes to the overall model.

## B. SHIP-TO-SHORE PHASE

### 1. Overview

Since the objectives of the thesis are to provide a user-friendly tractible combat model, a number of broad assumptions have been made regarding the exact method of employment of the LVA in the ship-to-shore

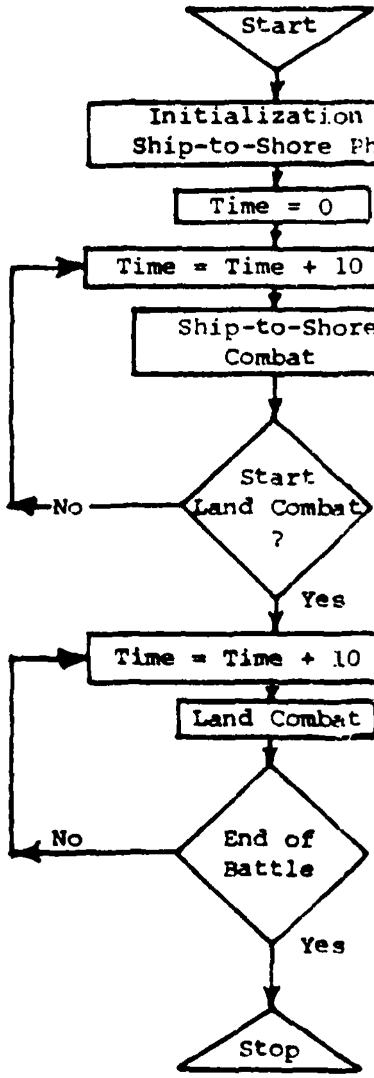



Figure 3-1. Generalized Flowchart for Small-Unit Amphibious Operation Combat Model

phase of the amphibious operation. First of all, it is envisioned that for command and control purposes, as well as for mine clearing operations, there will exist LVA approach lanes as depicted in Figure 3-2, along which columns of LVA will transit a 25-mile distance to shore from the Amphibious Task Force (ATF). The 25-mile distance is based upon recent requirements studies indicating that in future amphibious operations, due to the increased lethality of anti-ship missiles and long range artillery, it will be necessary to increase the Amphibious Task Force standoff distance to approximately 25 miles from shore to reduce the vulnerability of the amphibious shipping against this anticipated threat [Ref. 8]. Secondly, it is assumed that a maneuver area will exist within which the columns of waves of LVA will form into a conventional landing formation composed of waves of landing craft as prescribed by current doctrine.

The two previous assumptions set the stage for the primary assumption used in computing LVA force level attrition: that is, direct fire weapons will be assumed to be the primary anti-LVA threat--specifically, modified versions of current tank and antitank guided missiles (ATGM) assets. Although in reality some attrition of LVA can be expected in the maneuver area, it will be assumed that the critical exposure period will be that portion of time in the ship-to-shore movement that the first assault wave comes within 5,000 meters of the shore defenses until, up to, and including the arrival of the last assault wave ashore. Figure 3-3 is a flowchart depicting the general sequence of events of the ship-to-shore phase model.

2. LVA Movement Conceptualization

Two tactical decision variables were utilized for modeling LVA ship-to-shore movement:

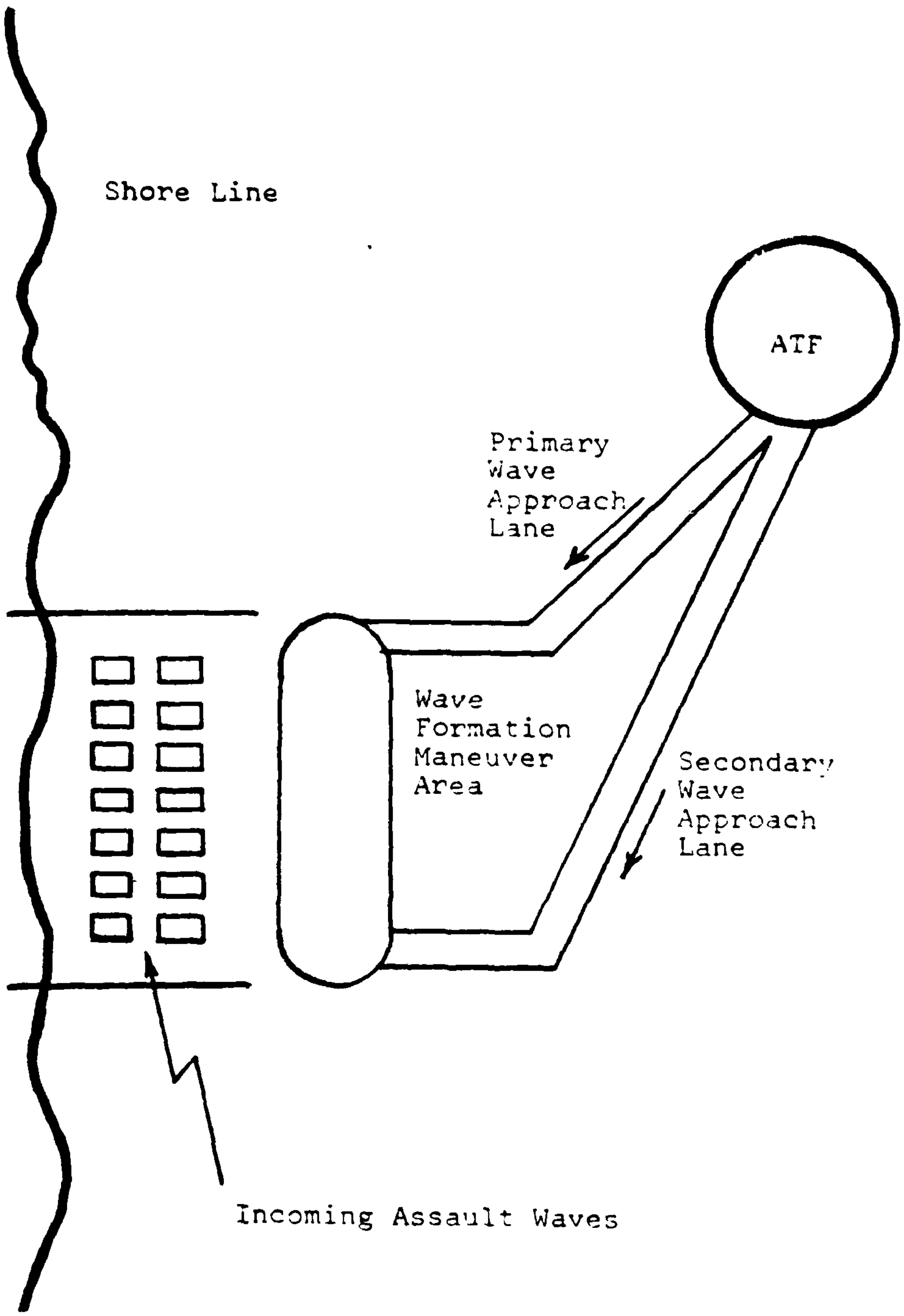



Figure 3-2. LVA Approach Conceptualization

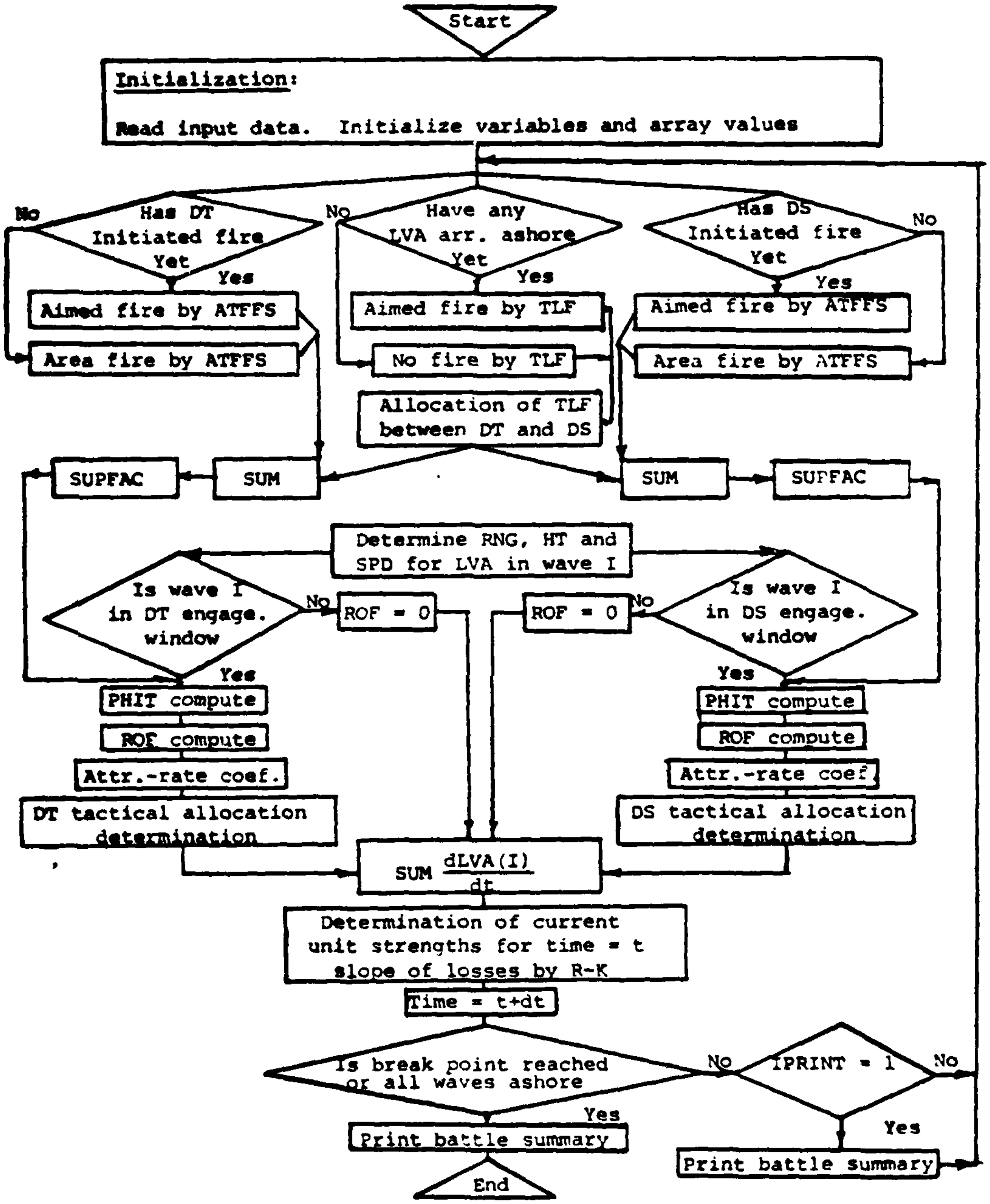



Figure 3-3. Generalized Flowchart for Ship-To-Shore Phase

--TBW is the decision variable for the time between successive waves. As TBW is shortened, coordination problems will arise resulting in confusion on the beach due to insufficient time provided for an assault wave to move inland prior to the next wave's arrival. The level of confusion generated by a short TBW must be balanced against the cost of not having sufficiently rapid initial buildup of offensive forces ashore.

--RD is the distance from the shoreline that each wave will commence the transition from planning model to displacement mode. This process will be termed a sequential wave transition since each of the assault waves sequentially performs the mode transition. This is illustrated in Figure 3-4. The reason for this transition is due to engineering stability requirements that this displacement configuration be achieved prior to crossing the surf line. The obvious effect of this transition is that exposure time to close-in direct-aimed fire will be created.

3. Overall Force Structure

The model aggregates the combat organizations involved in the ship-to-shore phase of the amphibious operation into several homogeneous combat units. Each unit is characterized by certain offensive and defensive capabilities in comparison to each of the other units.

Table 3-1 illustrates the combat organizations which have been explicitly modeled. The force level of each unit was represented by state variables as indicated. The initial force level for each unit is input-data to the model. This, therefore, permits the user to investigate alternative wave composition options as well as various defensive scenarios without having to make modifications to the model algorithm.

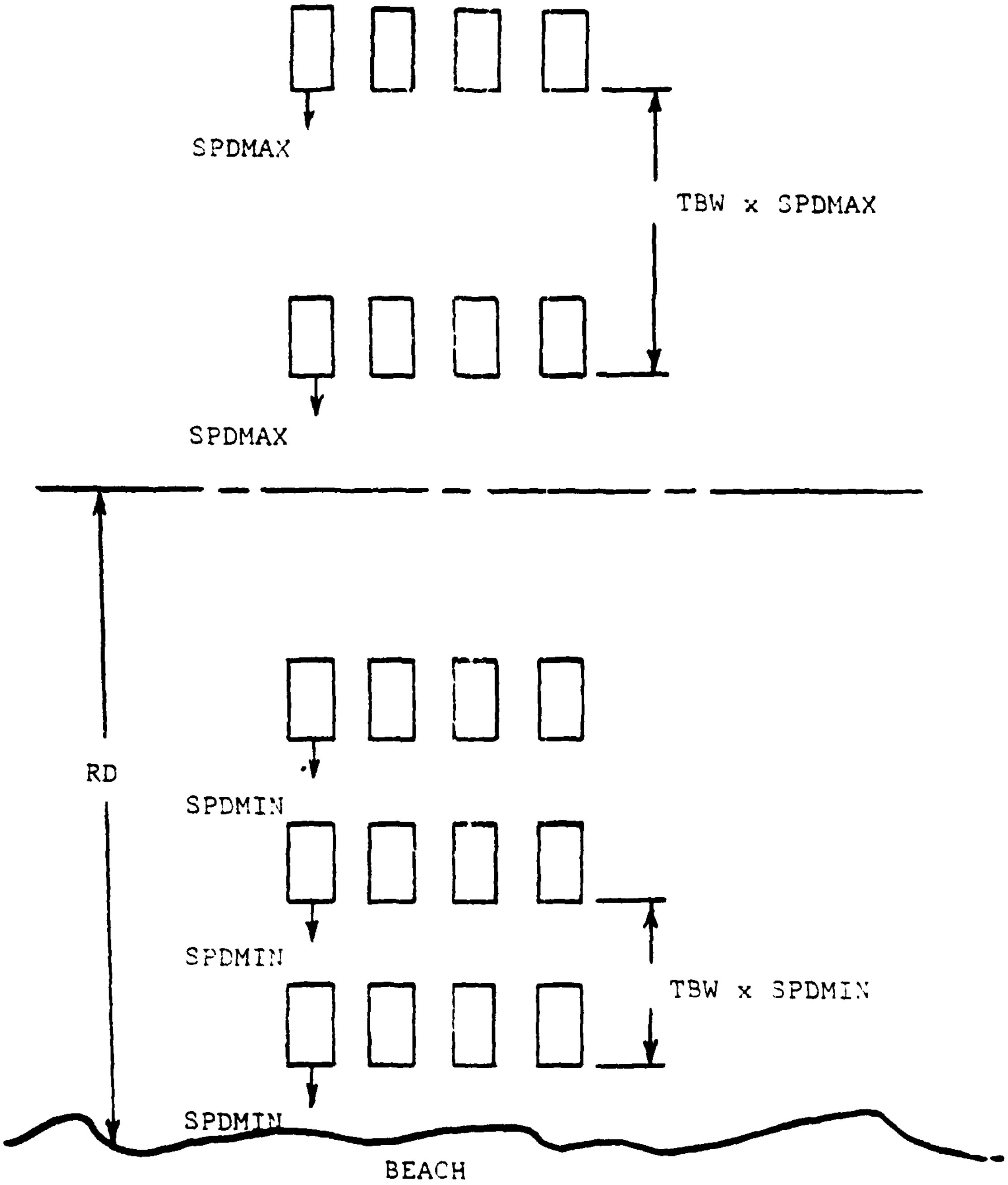



Figure 3-4. Tactical Employment Parameters--
Sequential Wave Transition

Table 3-1. State Variables Representing Combat Organizations

| Combat Organization | State Variable |
|---|---|
| Shore Defenses - Tank Assets | DT |
| Shore Defenses - ATGM Assets | DS |
| Incoming assault Waves of LVA representing waves 1 thru 5 | WV(I) I=1 thru 5 |
| A cumulative combat force comprised of those Marine ground units which have arrived on the beach and debarked their LVA | TLF |
| Fire support assets of the amphibious task force | ATFFS |

The tactical combat interactions that exist between these nine combat units within the overall force structure are illustrated in Figure 3-5.

4. Shore-Defense Scenario

The defensive scenario utilized in the model includes a force comprised of both tank (DT) and antitank guided missiles (DS). Tank and ATGM units are emplaced 75 meters inland of the waterline at an elevation of approximately 5-10 meters. The model does not explicitly maneuver or emplace individual tanks or ATGM systems within each unit, but aggregates the cumulative effects of the individual vehicles and weapons within each category.

a. Defensive Unit Force Levels

The state variables DT and DS represent the total unit "strengths" in each of the defensive unit categories. Specifically, a DT=3 indicates that within the shore defenses there exists a unit of tanks having a total combat effectiveness equivalent to three continuously

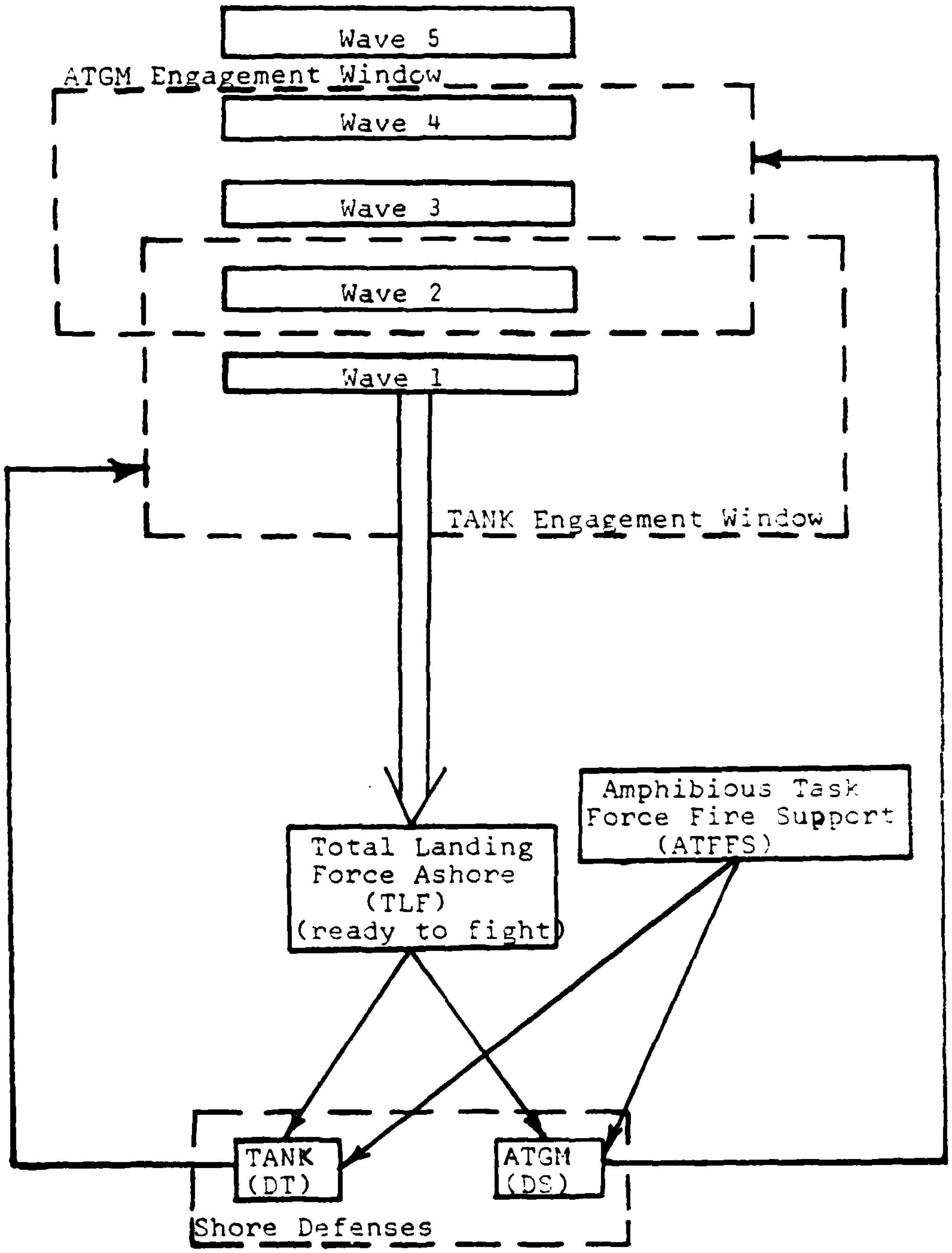



Figure 3-5. Force Interrelationships

firing independent weapon systems. A similar interpretation is applicable to the state variable DS.

b. Defensive Fire Allocation

The two categories of direct-fire weapons are assumed to engage targets (incoming LVA) according to a predetermined tactical scheme. The defensive "plan" was parameterized as follows:

(1) Window of Engagement. Each weapon category was assigned an engagement window as illustrated in Figure 3-6. Only those LVA located within the range window could be fired upon by the shore defensive forces. The windows are designated by the following input parameters:

| | TANK | ATGM |
|---|---|---|
| Maximum Engagement Range | TENGMX | SENGMX |
| Minimum Engagement Range | TENGMN | SENGMN |

(2) Engagement Rules. Additional defensive tactical criteria are implemented into the model logic according to the following rules of engagement:

--A defensive weapon may only engage the two closest incoming waves if more than two waves of LVA are at any time located within the weapon's engagement window.

--If only one wave of LVA is present in a weapon's engagement window, defensive fires of that particular weapon type will be distributed uniformly against the surviving LVA in that wave.

--If two waves of LVA are both contained within the engagement window, defensive fires of that particular weapon type will be distributed according to a tactical allocation submodel. A weighting factor, (DEFWT), input by the user is utilized in establishing the proportion of the total weapon strength to be allocated against the

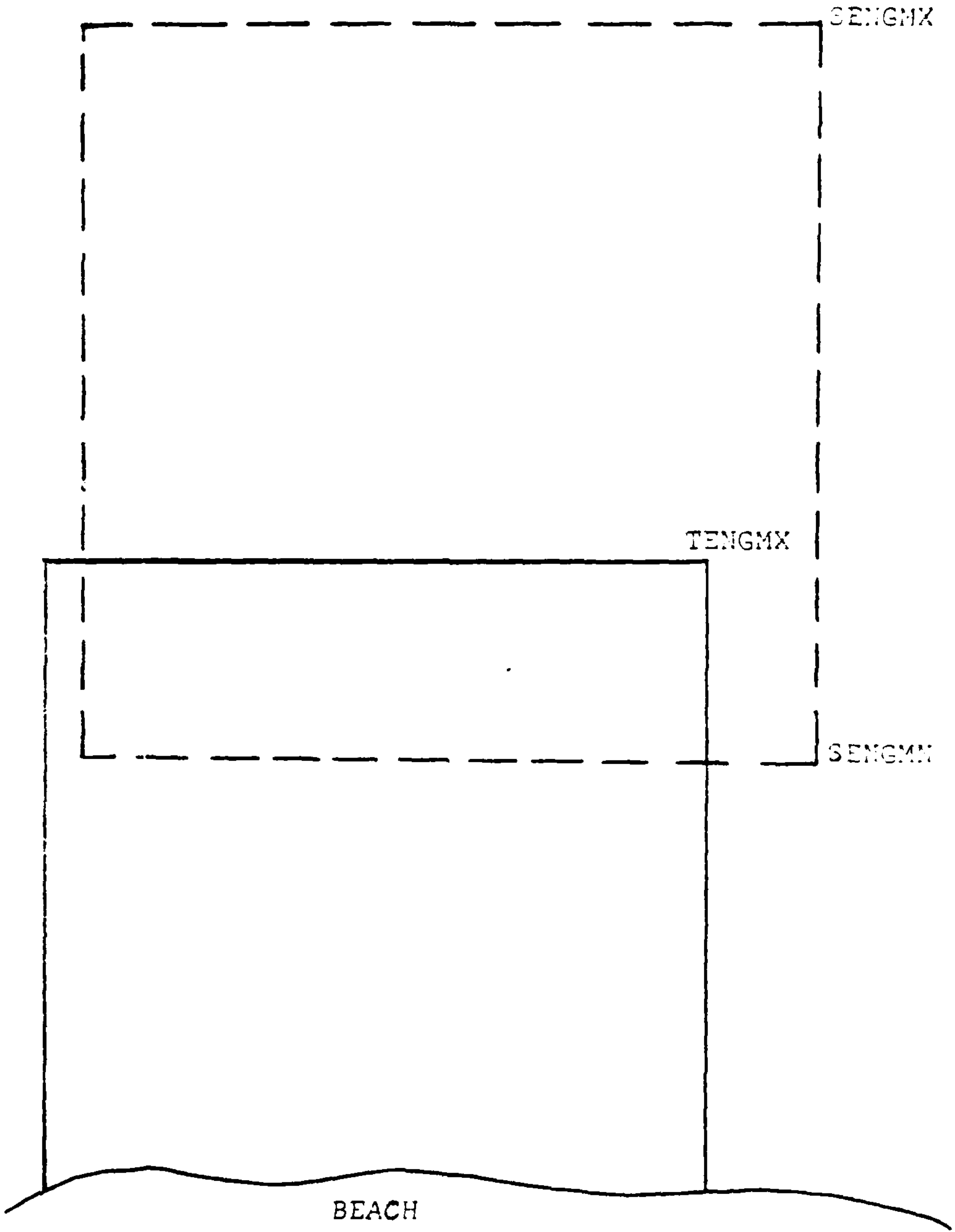



Figure 3-6. Engagement Window Parameters

surviving LVA's in each of the two waves. Specifically, if DEFWT(1) = 2, and DEFWT(2) = 1, then each surviving LVA in the closer of the two incoming waves would be allocated twice as much fire as surviving LVA in the seaward wave. For example, if waves three and four were both located within the ATGM engagement window, then the proportion of DS's fire allocated to surviving LVA in wave three would be:

$$\frac{\text{DEFWT}(1) \times \text{WV}(3)}{\text{DEFWT}(1) \times \text{WV}(3) + \text{DEFWT}(2) \times \text{WV}(4)} \times \text{DS}$$

where: WV(3) is the state variable for the current number of survivors in wave 3

c. Attrition-Rate Coefficient Computation

The classical Lanchester hypothesis for aimed-fire attrition is that the casualty rate of a unit is proportional to the size of the opposing force. If a Unit "A" is being engaged by a Unit "D", this action may be expressed by the differential equation:

$$\frac{dA}{dt} = -\text{Beta}_{DA} \times D$$

where: $\text{Beta}_{DA}$ is called the Lanchester attrition-rate coefficient

It is assumed that this functional relationship holds for each pairing (firing unit, target unit) over the small time interval dt. The credibility of the model relates the performance characteristic data together with the tactical and physical configurations for each of the combat units to derive the attrition-rate coefficients.

It was decided to express the attrition-rate coefficients as the product of the rate of fire (ROF) and the single shot kill probability (P(k)) as follows:

$$Beta_{DA} = P(k)_{DA} \times ROF_{DA}$$

where: DA represents a Unit "D" firing on a Unit "A"

More complicated models exist [Refs. 9 and 10], however, for the purposes of the modeling of the ship-to-shore LVA and defender attrition, this method was deemed sufficient.

Attrition-rate coefficients as described above were derived for each pairing (defensive weapon, target) yielding the ten variables:

$$Beta_{DT\text{-}WV(I)} = ROF_{DT\text{-}WV(I)} \times P(k)_{DT\text{-}WV(I)} \quad I = 1\text{-}5$$

and

$$Beta_{DS\text{-}WV(I)} = ROF_{DS\text{-}WV(I)} \times P(k)_{DS\text{-}WV(I)} \quad I = 1\text{-}5$$

A switch mechanism is incorporated into the rate of fire (ROF) factor by implementing the functional relationship:

$$ROF_{D\_\text{-}WV(I)} = \begin{cases} 0 & \text{if WV(I) is located outside the engagement window} \\ \dfrac{1}{TBF} & \text{if WV(I) is located within the engagement window} \end{cases}$$

where: TBF (Time Between Firings) is evaluated by

$$TBF = \text{Aim-Reload Time} + \frac{\text{Target Range}}{\text{Projectile Velocity + Target Speed}}$$

It should be noted that the relatively slow projectile velocities representative of anticipated ATGM assets in the future does cause such velocities to become significant in this computation.

The second factor used in determining each attrition-rate coefficient is the single-shot kill probability (P(k)). It is assumed

that a hit by a large caliber projectile would constitute a "kill" in that it most likely would inflict damage serious enough either to sink the LVA, or render it immobile, thus eliminating it from contributing to the buildup ashore. A second assumption is that both defensive weapon systems addressed would exhibit normally distributed, uncorrelated horizontal and vertical errors. Typical dispersion data, both mean and standard deviation, for the Tank and ATGM is required as input-data for the hit probability computations.

The suppressive effects of incoming fire upon each of the defensive units was considered a significant factor with respect to its effect upon the survivability of the incoming assault waves of LVA. It was assumed that the suppressive effect would significantly reduce a unit's rate of fire, and also increase the error standard deviation. The modeling of these suppression effects was accomplished by assigning a relative suppression factor (SUPFAC) in the interval 1, 2, to both the Tank and ATGM units. This factor was determined according to the following guidelines:

| | |
|---|---|
| SUPFAC = 1 | No incoming fires (i.e., the defensive unit casualty rate is zero) |
| SUPFAC = 2 | Maximum incoming fires (i.e., the defensive unit casualty rate is comparable to that realized upon full allocation of the ATF fire support assets) |

It was assumed that the aim-reload time (ARTM) would be increased by approximately 50 percent under the conditions represented by a SUPFAC = 2.0. Within the ROF submodel, this is expressed by the linear relationship:

$$ARTM_{SUP} = ARTM_{NONSUP} \times (0.5 + SUPFAC / 2.0)$$

Additionally, it was assumed that up to 100 percent increase in the error standard deviation could be expected under a maximum suppression environment, hence:

$$\text{ERROR STD}_{SUP} = \text{ERROR STD}_{NONSUP} \times \text{SUPFAC}$$

d. Defensive Breakpoint

It was assumed that if during the course of the ship-to-shore movement phase the defensive forces suffered a cumulative loss in excess of 70 percent of their initial force strength, the remaining shore defenses would withdraw and commencement of the land combat phase of the battle would take place.

5. LVA Assault Wave Conceptualization

The model is programmed to handle up to five incoming waves of LVA. The initial composition of these waves is input by the user by means of the variable WVINT. There are no limitations on the number of LVA's capable of being in each wave. However, the user is advised that the model was intended to model small-unit amphibious operations only.

a. Wave Posture

Model functions RNG, HT, and SPD are called upon within the model logic to generate the range, height, and speed, respectively, for each assault wave as time is incremented throughout the course of the ship-to-shore movement phase. The input of tactical employment parameters TBW and RD in conjunction with the physical design parameters SPDMAX, SPDMIN, HTMAX, and HTMIN for the LVA being evaluated uniquely determines the exact range offshore and vehicle configuration (planning/displacement) for each of the five waves. This information then is implemented in the rate of fire and hit probability calculations.

b. Ground Forces Ashore

As each assault wave arrives at the beach, the surviving strength of that wave is transferred to the variable TLF (Total Landing Force Ashore). TLF represents a ground combat force equal to that transported by the number of LVA survivors having arrived ashore. Once established, the TLF engages the two defensive units allocating its fires between the two defensive weapon categories in the same proportion as the number of surviving Tanks and ATGM's--that is:

$$TLF_{DT} = \frac{DT}{DT + DS} \times TLF$$

$$TLF_{DS} = \frac{DS}{DT + DS} \times TLF$$

The casualty rates applied against the DT and DS state that survivor variables are determined by means of the Lanchester aimed-fire attrition-rate coefficients $WBETA_{TLF - DT}$ and $WBETA_{TLF - DS}$ by the equations:

$$\frac{dDT}{dt} = -WBETA_{TLF - DT} \times TLF_{DT}$$

$$\frac{dDS}{dt} = -WBETA_{TLF - DS} \times TLF_{DS}$$

The computation of these WBETA coefficients is not performed within the model utilizing the detailed rate of fire and P(hit) arguments described previously, since in the original LVA assault model developed by Chadwick, these parameters were considered to be insignificant in relation to the overall model. Chadwick assumed his assault model would be used as an auxillary model to a higher-level model, and would receive values for these coefficients from that model.

6. <u>ATF Fire Support Conceptualization</u>

The impact of the amphibious task force's fire support assets contribute significantly to the combat effectiveness of the shore defense units. Characterizing each of the two defensive force units by a simple "located" or "not located" attribute, the attrition rates realized by these force units can be simplified substantially by the following approach.

a. "Not Located" Shore Defenses

At the commencement of the model it is assumed that the defensive units DT and DS are emplaced on shore at locations unknown to the ATF. The units initially are engaged as "not located" targets by area fire for which the following Lanchester area-fire equations are applicable:

$$\frac{dDT}{dt} = -(ALPHA_{DT} \times ATFFS) \times DT$$

$$\frac{dDS}{dt} = -(ALPHA_{DS} \times ATFFS) \times DS$$

The terms in parentheses on the right hand side of the equations are to be considered a generalized input parameter. The combat effectiveness of the ATF fire support assets is also to be considered relatively constant during this segment of combat time, and thus it is possible to synthesize these input factors by examining the attrition losses due to area realized in a previous full-scale model calibration run.

b. "Located" Shore Defenses

Once a particular defensive unit has initiated its engagement of incoming waves of LVA it is considered located. At this point it is

assumed that the ATF fire support organization will engage that defensive unit through the use of aimed fire. Again it is assumed that the loss rate will be in accordance with the Lanchester hypothesis for aimed fire, that is:

$$\frac{dDT}{dt} = {}^{-}Beta_{DT} \times ATFFS$$

$$\frac{dDS}{dt} = {}^{-}Beta_{DS} \times ATFFS$$

It should be noted that the right hand side of both of the equations is to be regarded as synthesized factors to be calibrated from a previous high-resolution application.

## C. LAND COMBAT PHASE

### 1. Overview

The land combat phase, like the ship-to-shore phase, has been modeled after broad assumptions have been made concerning the type of forces modeled and force attrition. These assumptions are quite similar in nature to those assumptions made in the ship-to-shore phase of the model which would be expected of similar Lanchester-type combat models.

The first assumption is that of homogeneous forces, which was made as a matter of convenience. The defensive forces will be modeled as a Tube-Launched, Optical-Guided, Wire Controlled missile (TOW) company made up of three TOW platoons located in three separate and fixed defensive positions. Each TOW platoon will be comprised of three TOW sections, and have the capability of withdrawing to an alternate position provided as input by the user. The aggressor force ashore will consist of the

consolidated surviving landing force ashore which has been redistributed into three offensive units.

The second assumption is that the aggressor force units will follow three user-defined routes as they advance toward the three defensive force positions. Routes can be supplied by the user, or defaulted to preassigned routes dictated by the program. However, only three routes can be utilized.

A line of sight (LOS) model written by Professor James Hartman, Naval Postgraduate School [Ref. 11], is used, adding great flexibility to the modeling of the terrain in the basic scenario. This has a direct impact on the probability of detection during any one time period (t,t+dt) which is shown as:

$$\begin{array}{c} \text{P(Unit i does not detect} \\ \text{Unit j in a time per-} \\ \text{iod t+dt)} \end{array} = \begin{array}{c} \text{P(Unit i does not detect Unit} \\ \text{j in a time period t+dt)} \\ \times \\ \text{P(Unit i does not detect Unit} \\ \text{j in a time period t,t+dt)} \end{array}$$

The first two assumptions provide a basis for applying the third assumption which is that attrition of opposing forces will be defined by direct-fire Lanchester differential equations similar to the ship-to-shore phase, only modeled in more detail. Figure 3-7 provides the scheme for the sequence and general flow of events in the model.

2. LVA Movement Conceptualization

a. General

In the original model, aggressor force and defensive force locations were modeled in two different ways. Defensive force locations

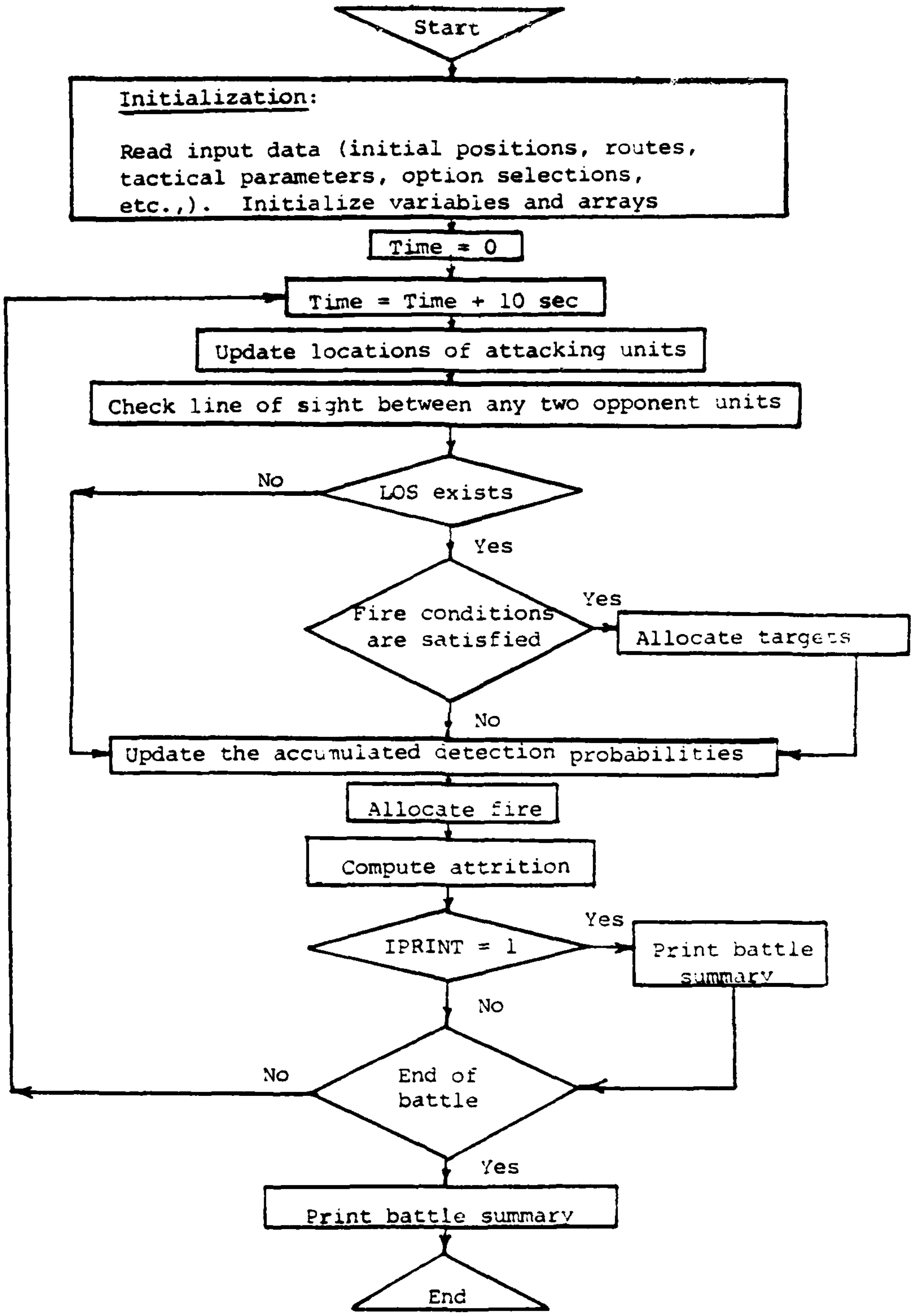



Figure 3-7. Generalized Flowchart for Land Combat

were left as user inputs, whereas aggressor force locations had been predetermined by the model builder, and could not be altered by the user. This allowed a flexibility of modeling defensive positions, but flexibility was limited because of the method of determining movement routes for the aggressors. Glenn Mills provided a user option to the model which permitted the user to model a variety of aggressor force movement scenarios. This option allows for the choice of attack routes and vehicle speed. In addition, the option is highly useful to the unfamiliar user of the model since unit locations and attack routes can be initially set to the model's default values. Different user selected parameters can be input as the user acquires a better understanding of the model's algorithm.

b. Model

Three predetermined routes are provided for aggressor force movements. Each route is subdivided into 40-meter length intervals, since a nonfiring aggressor unit is assumed to move one such interval during a time-step of 10 seconds (i.e., average speed of 9 mph). A firing aggressor unit is delayed a specified number of time-steps before moving to the next interval by the state variable NOD. Each interval in each route is represented by its center point coordinates, and by its direction. If an aggressor unit enters an interval along its associated route, then it is considered to be positioned in the center of the interval, generating a possible location error of $\pm$ 40 meters, since this is the distance between two consecutive intervals.

c. User-Defined Routes

The user is required to input the original location of each aggressor unit, and the locations of each of ten nodes he desires the

aggressor unit to move through as it advances on the defensive unit's position. This information, along with vehicle speed, is used to calculate route intervals that move the attacking unit through each of the designated nodes. A complete route would look like that depicted in Figure 3-8. The method used to complete the routes is as follows.

The straight-line ground distance between the first two adjacent nodes (DIST) is calculated as shown in Figure 3-8. The angle between the desired direction of movement and a straight west-to-east movement (a) is then calculated. Utilizing these quantities and the distance desired to be moved during each time-step (DST), the distance to be moved in the X and Y direction (XLN and YLN) is now computed as shown in Figure 3-9. These distances are added to the coordinates of the previous interval endpoint, point C in Figure 3-9, to determine the coordinates of the next interval endpoint, point D. This same distance is again added to compute the coordinates of the next endpoint, Point E. This process is continued until the distance from the last endpoint computed to the next node is less than DST. This general process is repeated for each pair of nodes until the entire route is completed, or the unit's force level is reduced to zero or the battle terminated, whichever comes first.

To insure that all intervals are of equal length, the computation of the first interval between any two nodes must be considered separately by taking into account the distance left over from the last computation between the previous two nodes. To accomplish this, the first interval takes the remaining distance (e) and adds it to an interval length (DST - e) for the first interval between any two nodes. This insures that each interval along the route is of length DST, which is the required length.

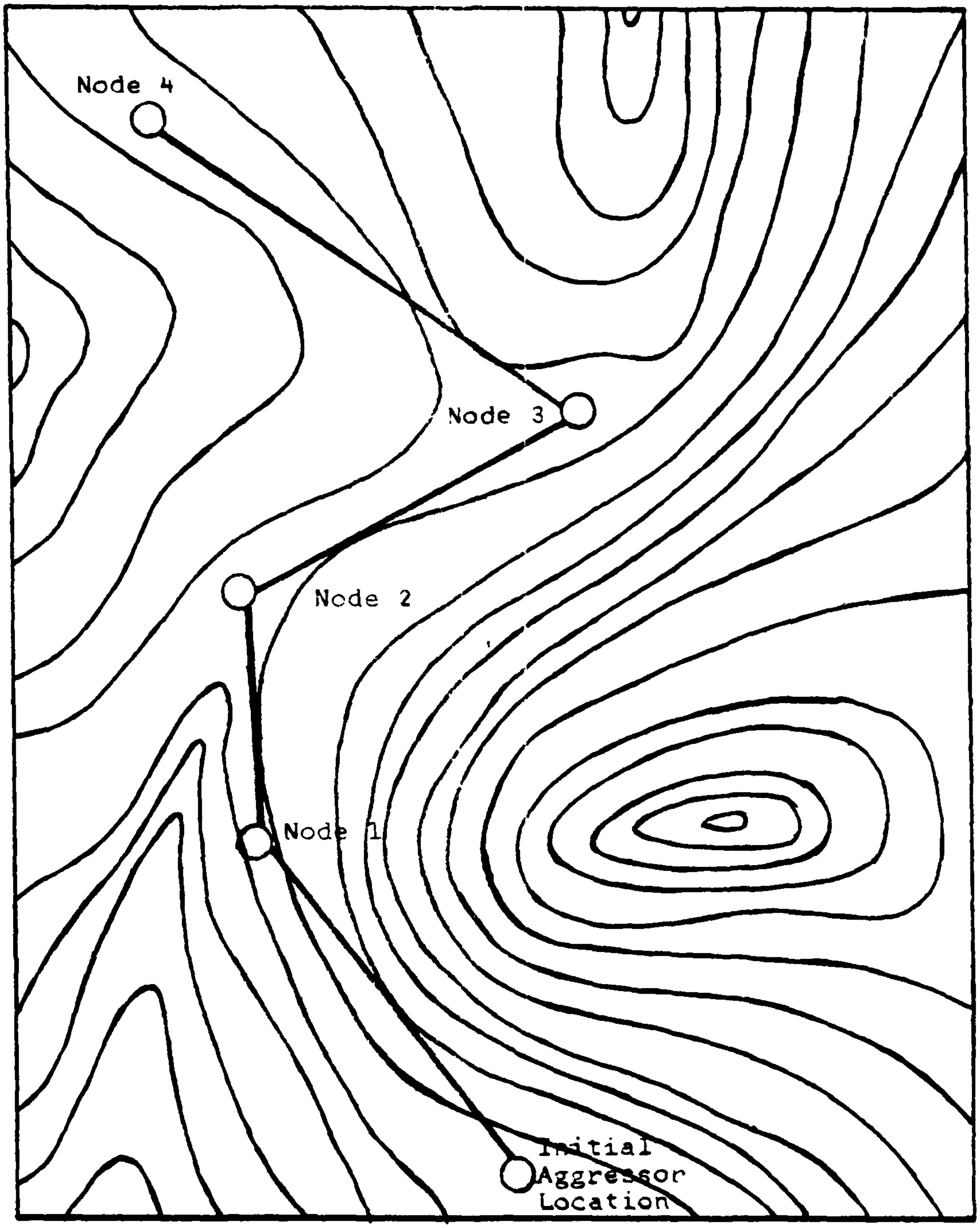
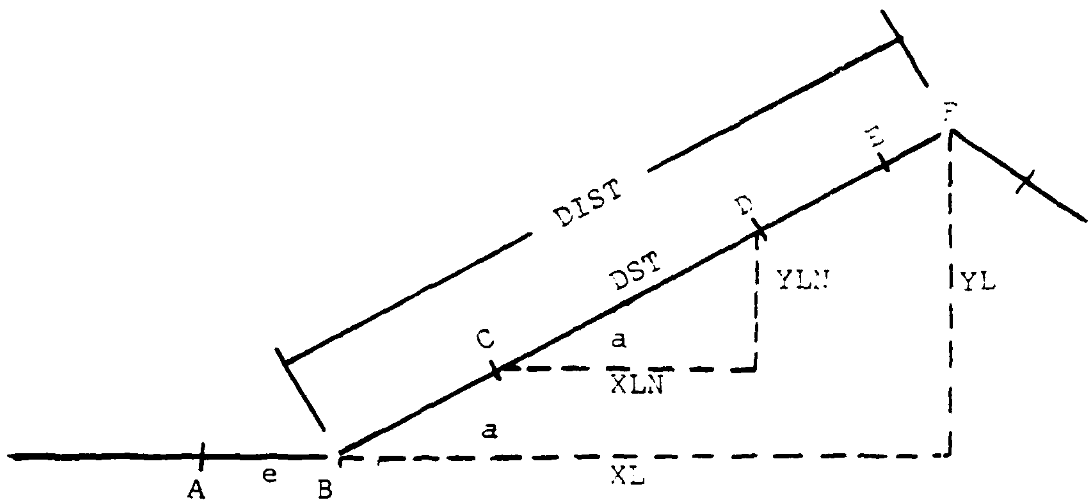



Figure 3-8. User Determined Routes




| NODE | COORDINATES | USE |
|---|---|---|
| A | XIC(N-1),YIC(N-1) | $(N-1)^{st}$ Interval Endpoint |
| B | XLOC(I,J) | User Inputed Node |
| C | XIC(N),YIC(N) | $N^{th}$ Interval Endpoint |
| D | XIC(N+1),YIC(N+1) | $(N+1)^{st}$ Interval Endpoint |
| E | XIC(N+2),YIC(N+2) | $(N+2)^{nd}$ Interval Endpoint |
| F | XLOC(I,J+1) | User Inputed Node |

$DIST = XL^2 + YL^2$

$a = TAN^{-1}\ (Y/XL)$, where $Y = YL$

e = distance less than DST at end of calculation of intervals between adjacent nodes.

$YLN = DST \times SIN(a)$ $\qquad$ $XLN = DST \times COS(a)$

Figure 3-9. Route Computation

### 3. LOS, Detection, and Fire Allocation

#### a. LOS

The existence of a line-of-sight between any two opposing units is determined utilizing a line-of-sight model written and programmed by Professor James K. Hartman, Naval Postgraduate School [Ref. 12], and is listed as Subroutine LOS in the land combat phase of the model. Professor Hartman's model utilizes a parametric terrain model proposed by Needles [Ref. 13], which represented terrain by modeling individual hill masses. Each hill is described by a bivariate normal density function, and fitted together to form a section of terrain utilizing the following information illustrated in Figure 3-10:

1) (Xc,Yc) - Coordinates of each hill's centerpoint
2) PEAK - Peak height of each hill
3) $\sigma_x$ - Standard deviation corresponding to the X-axis
4) $\sigma_y$ - Standard deviation corresponding to the Y-axis
5) (p) - Rotation factor

Once the terrain has been "mapped", the existence of a line-of-sight can be determined for each pair of opposing units. The information required to accomplish this is the location and elevation of each unit, as well as the height of the vehicle each unit uses. Professor Hartman's model yields the fraction of aggressing Unit A as seen by defending Unit B, and the fraction of defending Unit B as seen by aggressing Unit A. Figure 3-11 is used to illustrate this.

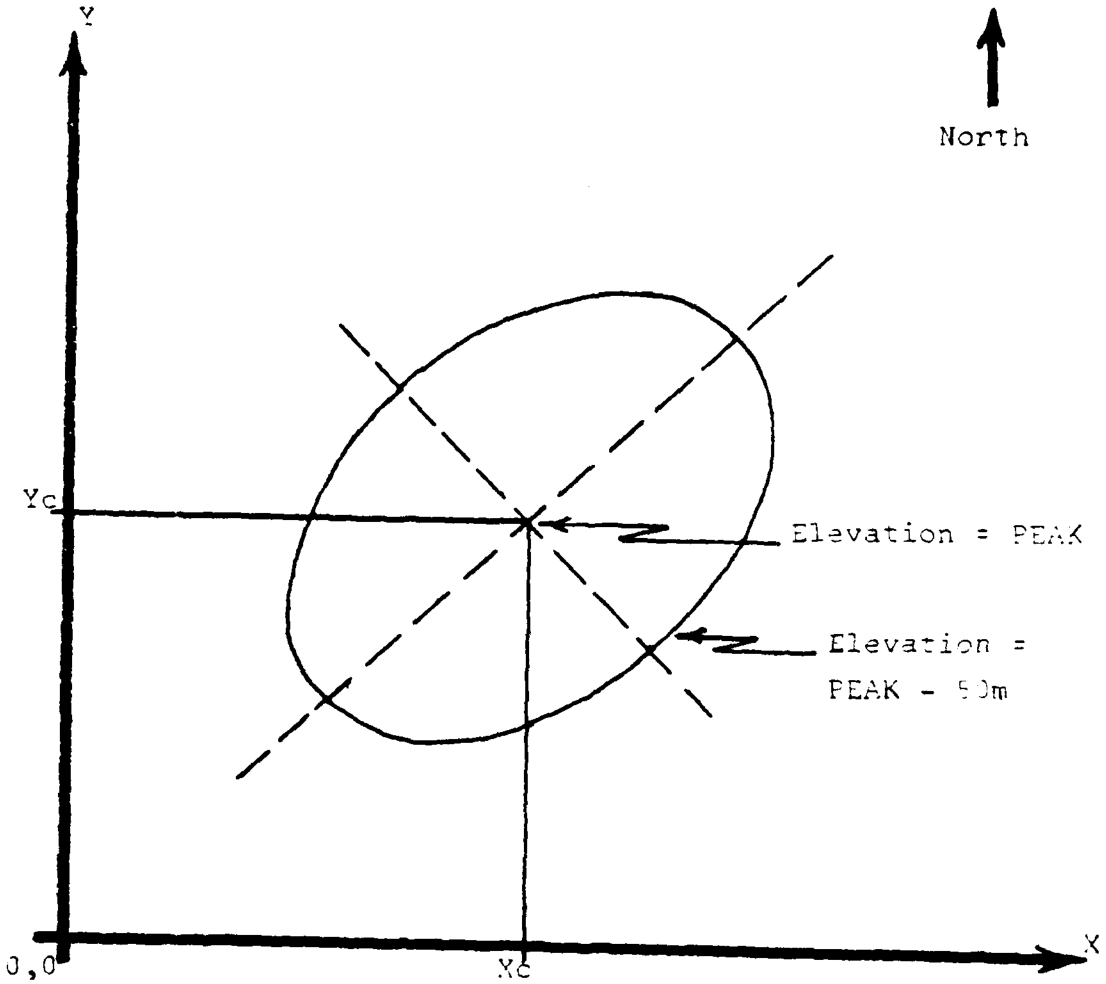



Figure 3-10. Terrain Conceptualization

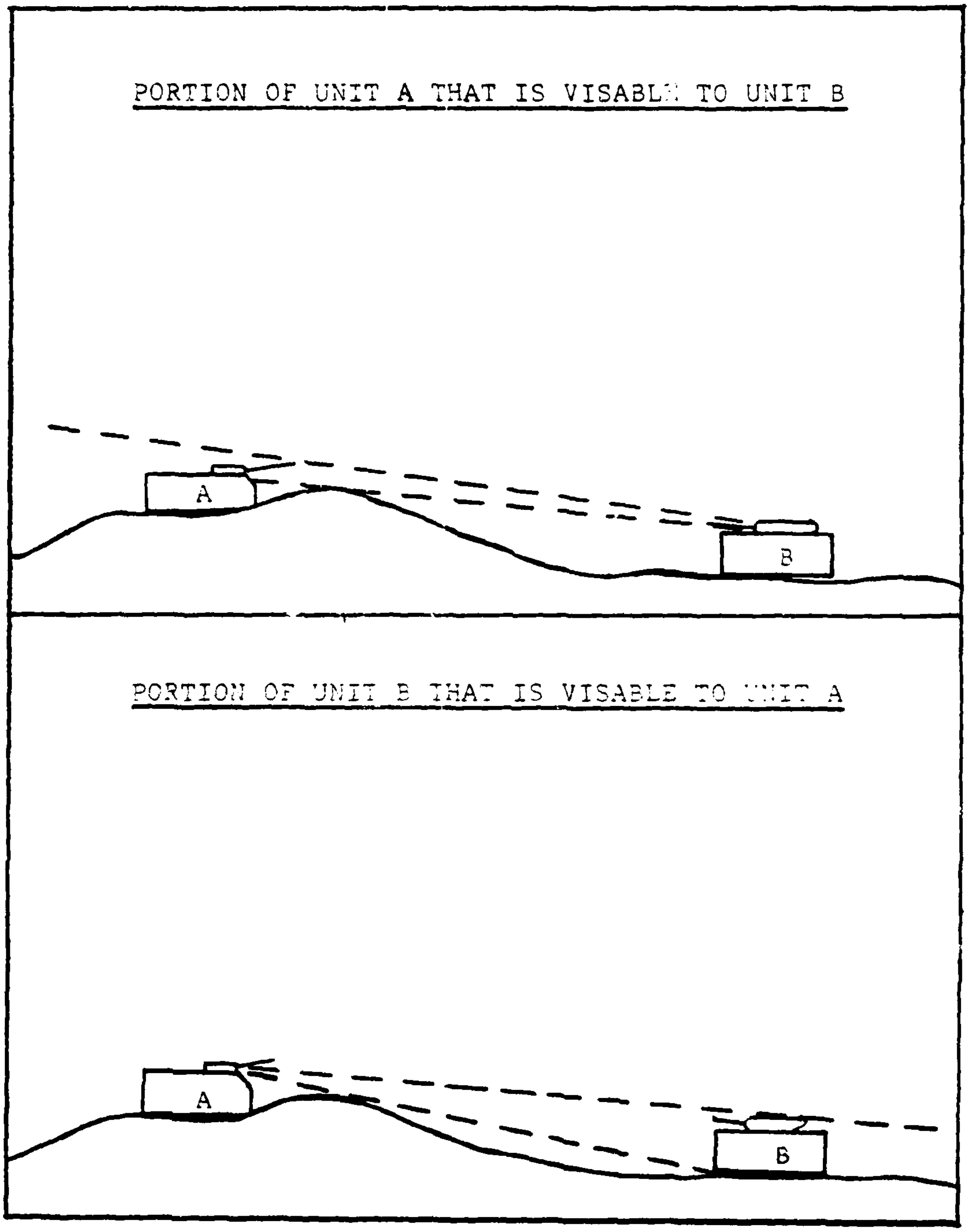



Figure 3-11. Partial LOS Conceptualization

b. Acquisition

The acquisition process was well-modeled in the original land combat model devised by Joseph Smoler. The model employs the concept of parallel acquisition, whereby the weapon system continuously searches for targets, even while engaging other targets. When such a weapon system kills its presently engaged target, it immediately can shift its fire to a new target, provided that such a target has been acquired either during the engagement of the previous target just killed, or earlier [Ref. 14]. A general description of the manner in which Smoler modeled target-acquisition is provided here. However, a more detailed description is provided in his thesis.

The probability that a Unit j is detected by a Unit i at time t+dt was modeled for four different combat situations in which the opposing forces might find themselves. These situations can be summarized as follows:

| Observer | Target |
|---|---|
| Not firing (t,t+dt) | Not firing (t,t+dt) |
| Not firing (t,t+dt) | Firing (t,t+dt) |
| Firing (t,t+dt) | Not firing (t,t+dt) |
| Firing (t,t+dt) | Firing (t,t+dt) |

The formulas derived to compute the probability of detection for each of these situations have a number of common variables, therefore their definitions are provided beforehand for clarity:

$P_{ij}(t=dt)$ = The probability that a typical firer in Unit i has acquired one or more targets of type j by time t+dt

$$Q_{ij}(t+dt) = [1 - P_{ij}(t+dt)]$$

$$QV_{ij}(t+dt) = e^{-\lambda_{ij} dt S_j(t)}$$

The probability that target j is not visually detected by Unit i during (t,t+dt) provided Unit j does not fire during this time interval

where: $S_j(t)$ = the number of survivors in Unit j at time t

and: $\lambda_{ij}$ = the nonfiring detection rate of one target in Unit j by one observer in Unit j

$$QP_{ij}(t+dt) = (1 - P_k)^{FR_j dt S_j(t)}$$

The probability that target j is not detected by a launch signature during (t,t+dt) provided that target j fires during this time interval

where: $P_k$ = The probability that one observer in Unit i is looking in a direction which enables him to detect target j

and: $FR_j$ = The firing rate of one firer in Unit j

The first situation occurs when neither the observer nor the target is firing during the interval (t,t+dt). This situation allows the observer to conduct search operations only, thereby maximizing the probability of detecting a target in his sector of responsibility, and has the target maximizing his probability of not being detected by exposure to an observer by a launch signature. Thus, the probability of not detecting in time interval (t,t+dt) is

$$Q_{ij}(t,t+dt) = Q_{ij}(t) \times QV_{ij}(t,dt)$$

The second situation occurs when the target is firing during the search interval (t,t+dt) while the observer is conducting only search operations. This provides the observer with additional information to assist in detection of the target. The observer will detect the target by the target's launch signature. Thus, the probability of not detecting in time interval (t,t+dt) is

$$Q_{ij}(t,t+dt) = Q_{ij}(t) \times (QV_{ij}(t,dt) + QP_{ij}(t,dt) - QV_{ij}(t,dt) \times QP_{ij}(t,dt))$$

The third situation occurs when the observer is firing during the search interval (t,t+dt) while the target is maximizing the probability of not being detected by not firing during the interval. The observer has lowered detection probability by diverting a portion of his force to firing on a known target. A new factor is introduced which will alter the probability of detection, namely the event:

A = The situation in which Unit j is within the field of view of Unit i, with at least one of the targets at which Unit i is firing

This states that Unit j, which is not currently firing, happens to expose itself to firing Unit i when firing Unit i is looking and firing on at least one other target in j's principal direction. Thus, the probability of not detecting in time interval (t,t+dt) is

$$Q_{ij}(t,dt) = \begin{cases} 0 & \text{if event A occurs} \\ g(n) & \text{if j is an aggressor unit and event } \bar{A} \text{ occurs} \\ Q_{ij}(t) & \text{if j is a defending unit and event } \bar{A} \text{ occurs} \end{cases}$$

where: $g(n)$ is an increasing function of n, where n is the number of time intervals elapsed since time t.

and: $g(0) = Q_{ij}(t)$

$$Q_{ij}(t) \leqq g(n) \leqq 1.0 \text{ for all } n$$

The fourth situation occurs when both the observer and target are firing during the interval (t,t+dt). In this situation the observer has minimized his searching capability, and the target has maximized its probability of being detected. Thus, the probability of not detecting in time interval (t,t+dt) is

$$Q_{ij}(t,t+dt) = \begin{cases} Q_{ij}(t) \times QV^{*}_{ij}(t,dt) & \text{if event A occurs} \\ g(n) & \text{if } j \text{ is an aggressor unit and event } \overline{A} \text{ occurs} \\ Q_{ij}(t) & \text{if } j \text{ is a defender unit and event } \overline{A} \text{ occurs} \end{cases}$$

where: $QV^{*}_{ij}(t,dt) = e^{-\lambda^{*}_{ij} dt S^{*}_{j}(t)}$

and: $\lambda^{*}_{ij} = \;_{ij} \times RF$

RF = Reduction Factor (the detection rate of Unit i has to be reduced since this unit fires during (t,t+dt) and the search for targets is not as effective as for a nonfiring unit)

$S^{*}_{j}(t) = S_{j}(t) \times ({}_{K}\Sigma_{k} \, PTT_{iK})$

$PTT_{iK}$ = proportion of Unit i allocated to Unit K

k = (Unit K is engaged by Unit i and Unit j is within the field of view of Unit i while observing Unit K)

If a line-of-sight does not exist between observer i and target j, then no accumulation of detection probability will take place during the current time interval (i.e., $P_{ij}(t)$ will remain the same). However, if a line-of-sight does not exist throughout more than three consecutive time intervals, then the $P_{ij}$ is set to zero (i.e., $P_{ij}(t) = 0$) and the accumulation process will start again from zero if a line-of-sight is acquired at a later point in the battle. The motivation for this decision rule is seen by the observation that even if observer i loses a line-of-sight with target j for a short period of time, he still probably has some idea of where to expect the target to reappear.

c. *Non-Firing Detection Rate*

The situations that occurred when the target was in a non-firing status had detection probability functions that had as a parameter $\lambda_{ij}$, a non-firing detection rate. The manner in which the model derives this rate is quite detailed, and deserves attention.

To begin, each firer in an observing unit is assigned a search section (or sector of responsibility) which is characterized by two parameters (see Figure 3-12). These parameters are the section width (ISECWD), and the primary direction of search (IPRDIR). Furthermore, it is assumed that the search direction within a section of search has the following probability density function known as the LIMICON Function:

$$f(\theta) = A + B \cos \theta \quad -D \leq \theta \leq D$$

where:

$$D = \text{ISECWD}/2$$

$$A = {}^{-}B \cos D$$

$$B = \frac{1}{2\,(\sin D - D \cos D)}$$

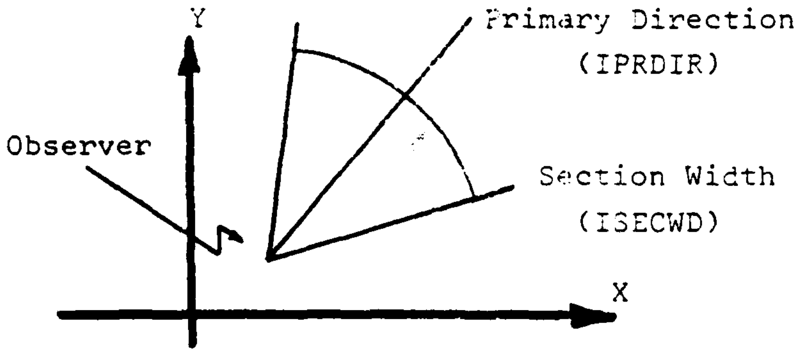



Figure 3-12. Search Direction

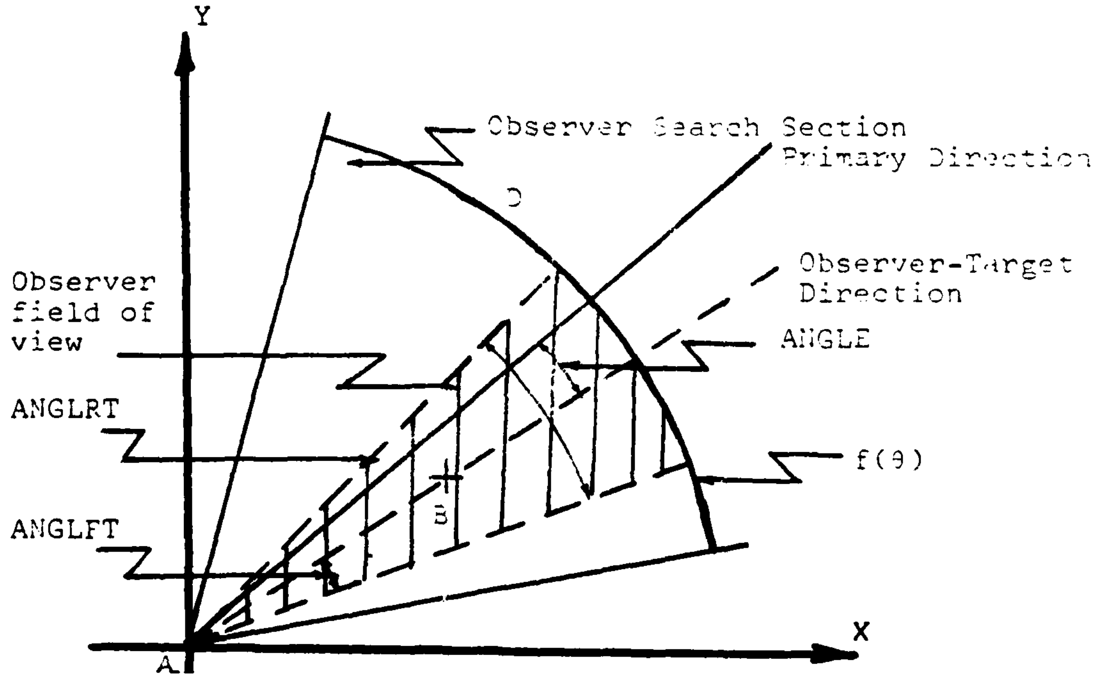



Figure 3-13. Observer-Target Scheme
(A = Observer, B = Target)

$\theta = \emptyset$ corresponds to the observer's primary direction of search

note: A and B are chosen such that

$$\int_{-D}^{D} f(0)\, d\theta = 1$$

To determine the probability that observer A is looking in a direction which enables him to detect target B, $P_k$ is the value of the LIMICON function integrated from an angular value up to 15° on either side of the primary direction of fire, specifically:

$$P_k = \int_{ANGRT}^{ANGLFT} f(\theta)d\theta \quad = \quad \text{shaded area, Figure 3-13}$$

where: $$ANGLFT = \begin{cases} ANGLE + 15^\circ & \text{if } ANGLE + 15^\circ \leq D \\ D & \text{if } ANGLE + 15^\circ > D \end{cases}$$

and: ANGLE = the absolute value of the angle betweer the the primary direction (IPRDIR) and the observer-target direction (OTANG)

ANGRT = ANGLE - 15°

Now, given that observer A is looking in a direction $\alpha$ such that ANGRT $\leq \alpha \leq$ ANGLFT, the conditional detection rate ($\lambda_{ab}$ | ANGRT $\leq \alpha$ $\leq$ ANGLFT) is determined by a regression curve [Ref. 15] which is a function of the terrain, target horizontal velocity, and the equivalent range for a full height target. This detection rate of one observer detecting one target becomes

$$\lambda_{ab} = (\lambda_{ab} \mid ANGRT \leq \alpha \leq ANGLFT) \times P_k$$

d. Fire Allocation

Three conditions are necessary for Unit j to be classified as a target for Unit i. First, a line-of-sight must exist between Unit i and Unit j. Second, the range between the units must be within the maximum range of Unit i's weapon system. Lastly, the probability that a detection of Unit j is made by an observer in Unit i in the time period t+dt must be greater than 0.00.

Once these conditions are satisfied, the manner in which fire is allocated to a target depends upon how many targets are to share in the firepower of Unit i, and what distance exists between i and the new target in relation to the other targets under fire. The priority of fire naturally will go to the closest target since it is of a greater threat to Unit i than the more distant targets. The amount of firepower available from Unit i is naturally a function of the percentage of surviving force available to fire in Unit i.

4. Attrition

Attrition of forces is assessed based upon variable coefficient Lanchester equations of modern warfare [Ref. 16]. This method of attrition assessment was used by David Chadwick in the ship-to-shore phase of the model, however, in less detail than was modeled by Joseph Smoler in the land combat phase of the model. The "extra" detail provided by Joseph Smoler is the generation of the conditional probability of a kill given a hit. This probability was stated by Chadwick as a user-supplied input parameter.

The restriction of the model to aimed-fire weapons systems and homogeneous forces allows for the attrition of forces to be assessed using variable coefficient Lanchester equations of modern warfare.

The attrition for a defending Unit j is described by the following differential equation:

$$\frac{dS_j(t)}{dt} = {}^{-}(A_{ij} \times PROP_{ij}) \times S_i(t)$$

where: $S_k(t)$ = The number of survivors in Unit k at time t

$A_{ij}$ = The rate at which one firer of Unit i kills Unit j targets (attrition rate of Unit j by one firer of Unit i)

$PROP_{kl}$ = Proportion of Unit k allocated to fire against a Unit l

These basic differential equations of force-on-force attrition were approximated by the following Euler-Cauchy difference equations:

$$S_i(t+dt) = \text{Max}(0, S_i(t) - \Sigma A_{ji}(S_j(t) \times PROP_{ji})dt$$

for each defending Unit i

and:

$$S_j(t+dt) = \text{Max}(0, s_j(t) - \Sigma A_{ij}(S_i(t) \times PROP_{ij})dt$$

for each aggressor Unit j

The manner in which the attrition-rate coefficient $A_{ij}$ is derived stochastically already has been discussed in the model enhancement chapter, therefore, only a description of how the deterministic attrition-rate coefficient is derived will be mentioned here.

The attrition-rate coefficient, $A_{ij}$, for each equation is computed according to the equation:

$$A_{ij} = \frac{1}{E[T_{ij}]}$$

where: $T_{ij}$ = the time for one firer of Unit i to kill one target of Unit j under the conditions in the present time interval

$T_{ij}$ is computed using the Bonder-Farrell formula [Ref. 17]:

$$E[T_{ij}] = t_a + t_1 + \frac{t_h + t_f}{P(k|h)} + \frac{1 - P(h|h)}{P(k|h)} + P(h|h) - P(h)$$

where:

$t_a$ = Time to acquire a target

$t_1$ = Time to fire first round after a target is acquired

$t_h$ = Time to fire a round following a hit

$t_m$ = Time to fire a round following a miss

$t_f$ = Projectile's time of flight

$P(h)$ = Probability of a hit on first round

$P(h|h)$ = Probability of a hit on a round given that the prior round fired was a hit

$P(h|m)$ = Probability of a hit on a round given that the prior round fired was a miss

$P(k|h)$ = Probability of a hit on a round given that the round fired was a hit

There are two assumptions of the Bonder-Farrell formula that are implied by the model. The first assumption is that fire is Markov-Dependent in that the probability of a hit of any round depends only upon the result of the previous round. The second assumption is that a Geometric Distribution describes the parameter $P(k|h)$ in that accumulated damage is considered to be negligible.

The expected value of $T_{ij}$, $E[T_{ij}]$, may now be expressed for each weapon system in the model. It is assumed that for the TOW

weapon system $P(k|h) = 1.0$, and $P(h|m) = P(h|h) = P(h)$, which results in the reduced formula:

$$E[T_{ij}] = t_a + t_l + t_f + \frac{(t_m + t_f) \times (1 - P(h))}{P(h)}$$

If the firing weapon system is a tank, then it is assumed that $P(k|h) = 1.0$ (due to a lack of information), and that $t_f = 0.0$ (due to the velocity of the projectile). Thus, in this case the formula becomes:

$$E[T_{ij}] = t_a + t_l + \frac{t_m}{P(h|m)} \times (1 - P(h))$$

It should be noted that all targets were considered to be stationary throughout the attrition process. This is obvious in the case of the stationary defending forces, and was assumed to be the case for the aggressor forces due to the fact that the hit probability of a TOW against a moving target is almost the same as for a stationary target.

5. Battle Termination

Two criteria were used as rules governing battle termination. The first criterion was the annihilation (zero force level) of one of the two forces. The second criterion was that the distance between defender and aggressor forces is too small.

The first criterion is an intuitively obvious reason for terminating the battle, and thus easy to model. However, although the reasons for the second criterion might be as obvious, the modeling of this is not simple. The manner in which Glenn Mills modeled it was to compute the distance between each attacking sub-unit on which casualties were being assessed (i.e., still alive), and each defending

sub-unit that was still alive. If any one of these distances between active sub-units was too close, the battle was considered to have reduced to close-in, hand-to-hand combat. The outcome of this type of combat is not currently provided for in the model, and for this reason the battle is simply terminated at this point. However, to insure that the aggressor units do not pass by the flanks of the remaining defending forces and remain outside termination distance, a check is made of the location coordinates of each sub-unit. If any aggressing sub-unit's X coordinate places the unit beyond the location of the most forward defending sub-unit still in the battle, the battle also is terminated.

The specification of the distance between forces for battle termination is left as a user-input, which provides added flexibility of breakpoint distance analysis. In particular, it lends itself to the study of optimum breakpoint distances for various weapons systems on the battlefield.

## IV. FUTURE ENHANCEMENTS

A small-unit amphibious operation combat model has been presented in this thesis which emphasizes the simplistic and avoids the abstract to provide an understandable and, more importantly, a useable combat model for students of combat modeling. However, the combat model presented has the potential of being developed into a much more refined model which could be studied and utilized by more experienced combat modelers. Therefore, several enhancements which might be of some benefit to the more experienced modeler are mentioned here as possible approaches that could be taken in refining the present model.

### A. HETEROGENEOUS FORCES IN THE LAND COMBAT PHASE

The current land combat phase of the model involves combat between homogeneous forces only--that is, each force is comprised of only one weapon system type. This type of force structure was intentionally modeled to maintain a relatively simple model to understand and work with. However, added flexibility could be attained by modeling multiple weapons system types for each of the opposing forces. This would allow the user to analyze the effect that different force mixes would have on battle outcome.

The addition of different weapons system types within a single unit would require extensive restructuring of the attrition process currently used in this model. Although Lanchester equations still could be utilized in computing direct-fire weapon system attrition, separate Lanchester equations would have to be provided for each weapon system.

Furthermore, with the addition of indirect-fire weapon systems (i.e., artillery, naval gunfire, and close air support) Lanchester equations for area-fire would have to be implemented for each area-fire weapon system type. The total attrition of any particular unit then would be the summation of the damage assessed by each weapons system type on the target being attrited.

An enhancement of this type would result in more realism at the cost of longer execution time, and a more complicated attrition process. Since the original intent of the thesis was to provide a simple model to understand, it would be advisable to retain a copy of the original model prior to adding this enhancement. Then a simple model would still be available to the less experienced combat modeling students, while a more detailed model would provide the realism that more experienced modelers would demand.

## B. LOGISTICAL SUPPORT

Logistical support is one of the most overlooked factors of combat in the development of combat models. The influence that the resupply of fuel and ammunition alone have on the outcome of a battle is obvious and deserves attention.

Ammunition and fuel consumption could be modeled along the same lines as attrition (i.e., through the use of expected values of consumption). When ammunition or fuel on hand reaches a specified critical level, a unit could be restricted in movement, or experience a reduced level of fighting effectiveness and maneuverability (based on a shortage of ammunition and fuel) until resupply of the critical resource could be obtained.

The amount expended of these resources would necessarily be a function of the number of surviving firers in the unit, the number of vehicles available to transport the unit, and the number of targets engaged by the unit at any one time interval. The expected values of these items then could be used in computing the expected rate of consumption of ammunition and fuel. Therefore, the overall process could be modeled by initially allocating specific levels of these resources (i.e., ammunition and fuel) to each unit at the commencement of the battle, and subtracting the expected expenditure of the ammunition and fuel of a particular unit based upon the expected number of survivors firing on engaged targets, and the distance traveled by the expected number of surviving vehicles of the unit.

## C. GRAPHICAL BATTLE SUMMARY

A graphical display of what is taking place on the battlefield can be worth a thousand words to the user of a combat model. Plotting unit locations and force levels on a display of the actual terrain fought upon would eliminate time-consuming interpretation of these results from a printed battle summary report. An enhancement of this sort would serve both the experienced and inexperienced users of the model. The inexperienced user would have results displayed in a much more understandable format, while the experienced user would be able to study variant combat scenarios with much less effort and time expended.

# V. FINAL REMARKS

The purpose of the model that has been developed is to illustrate a number of underlying concepts of combat modeling which have been addressed in this study. Therefore, it seems appropriate to readdress these concepts to allow the reader to reflect upon them in light of what has just been presented.

## A. INTEGRATING INITIALLY INDEPENDENT COMBAT MODELS

The model developed here was made up of two sub-models: ship-to-shore and land combat models. These sub-models, as discussed earlier, utilized similar combat modeling methodology (i.e., Lanchester equations) in computing force level attrition. However, each sub-model was developed by different individuals, which created several problems when the two separate sub-models were integrated into a singular continuous flow algorithm. In particular, individualized FORTRAN coding techniques and documentation of state variables within the program structure required the restructuring of major portions of FORTRAN code to make the overall combat model tractible and understandable. This serves to illustrate the need for a standardized programming technique to be applied to programming of combat models, and highlights the need for proper planning and coordination in development of large scale combat models by teams of combat modelers.

## B. THE USER-ORIENTED APPROACH TO COMBAT MODELING

This thesis illustrates the desirability of a user-friendly approach to combat modeling. It was a major contention of the thesis

that this approach to combat modeling has not been closely addressed by combat modelers providing combat models for the United States military. Furthermore, it was mentioned that the lack of concern given to this approach of combat modeling might help to explain the lack of enthusiasm exhibited by the United States military in utilizing combat models for the training of field commanders and staffs. The thesis had as one of its purposes, the presentation of a combat model designed to be easily understood and utilized by intended users, combat modeling students. Combat models should be designed and documented with the user's capabilities and needs in mind, as opposed to those of the programmer.

## C. A COMBAT MODEL FOR STUDENT USE

The small-unit amphibious operation combat model presented here is a basic Lanchester-type combat model which has been designed with a low level of complexity in order that it might be understood more easily, and studied by students of combat modeling. It has been recognized that combat modeling students may have little or no experience of the governing theory, and therefore would comprehend the theory of combat modeling more easily by utilizing and understanding its basic application. For this reason, enhancements that would increase the complexity of the model are discouraged, and enhancements that would make the model more understandable (i.e., graphical battle summary reports) are strongly encouraged.

APPENDIX A

USER'S MANUAL

for the

SMALL-UNIT AMPHIBIOUS OPERATION COMBAT MODEL

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# I. INTRODUCTION

The purpose of this manual is to familiarize the user with the model, and to provide administrative information describing how the potential user would access and run the model.

The small-unit amphibious operation combat model is a two-phased combat model which conducts both ship-to-shore and land combat. The model uses both aimed and area-fire Lanchester-type equations for casualty assessment. The battle is initiated by an amphibious task force positioned 25 miles offshore from an opposing defensive force which is illustrated in Figure A-1. If an amphibious landing is successful, land combat will be conducted inland over a 10 x 10 km piece of terrain representing an area east of Fulda, West Germany, known as the Fulda Gap, which is depicted in Figure A-2.

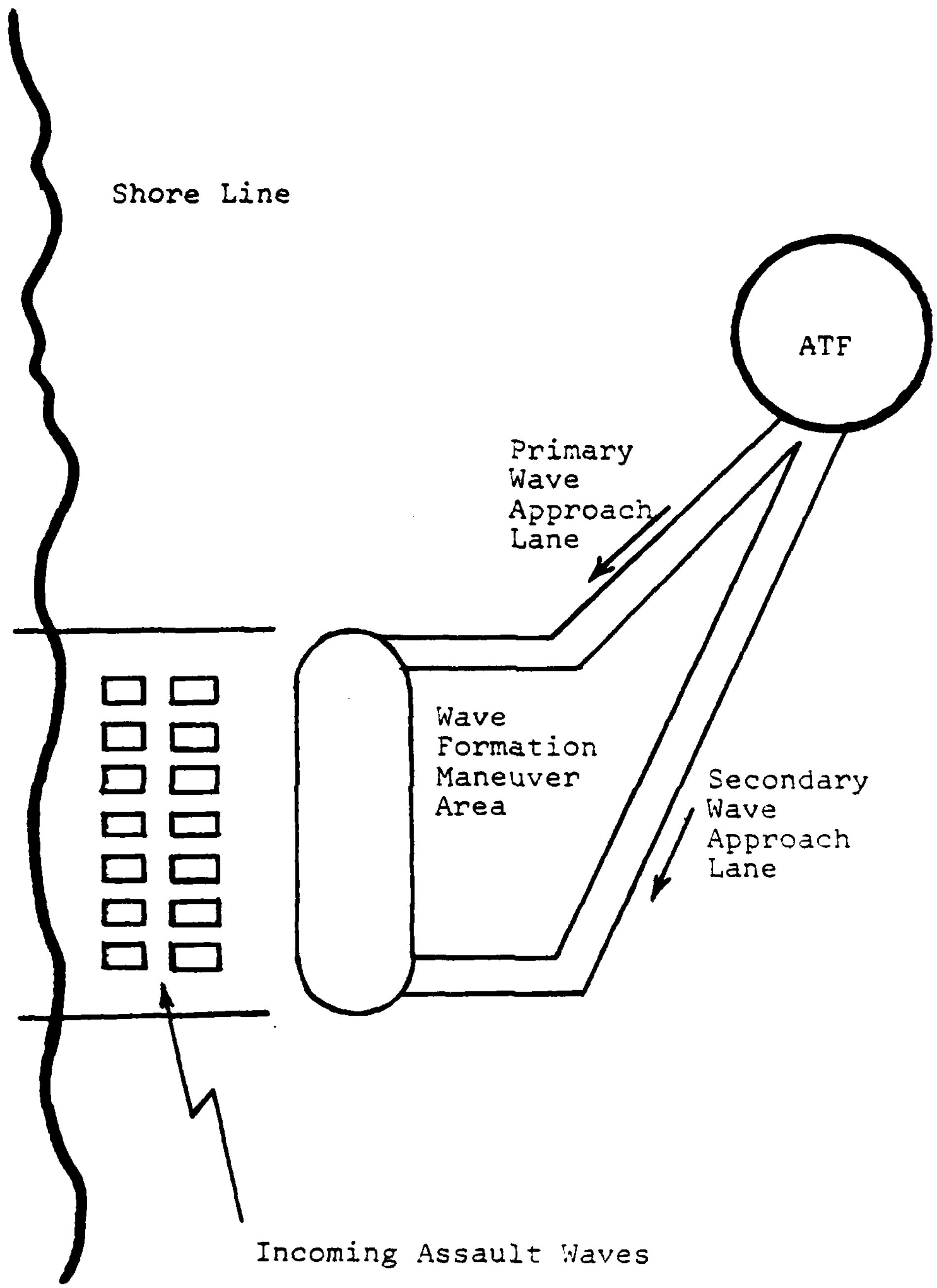


Figure A-1. LVA Approach Conceptualization

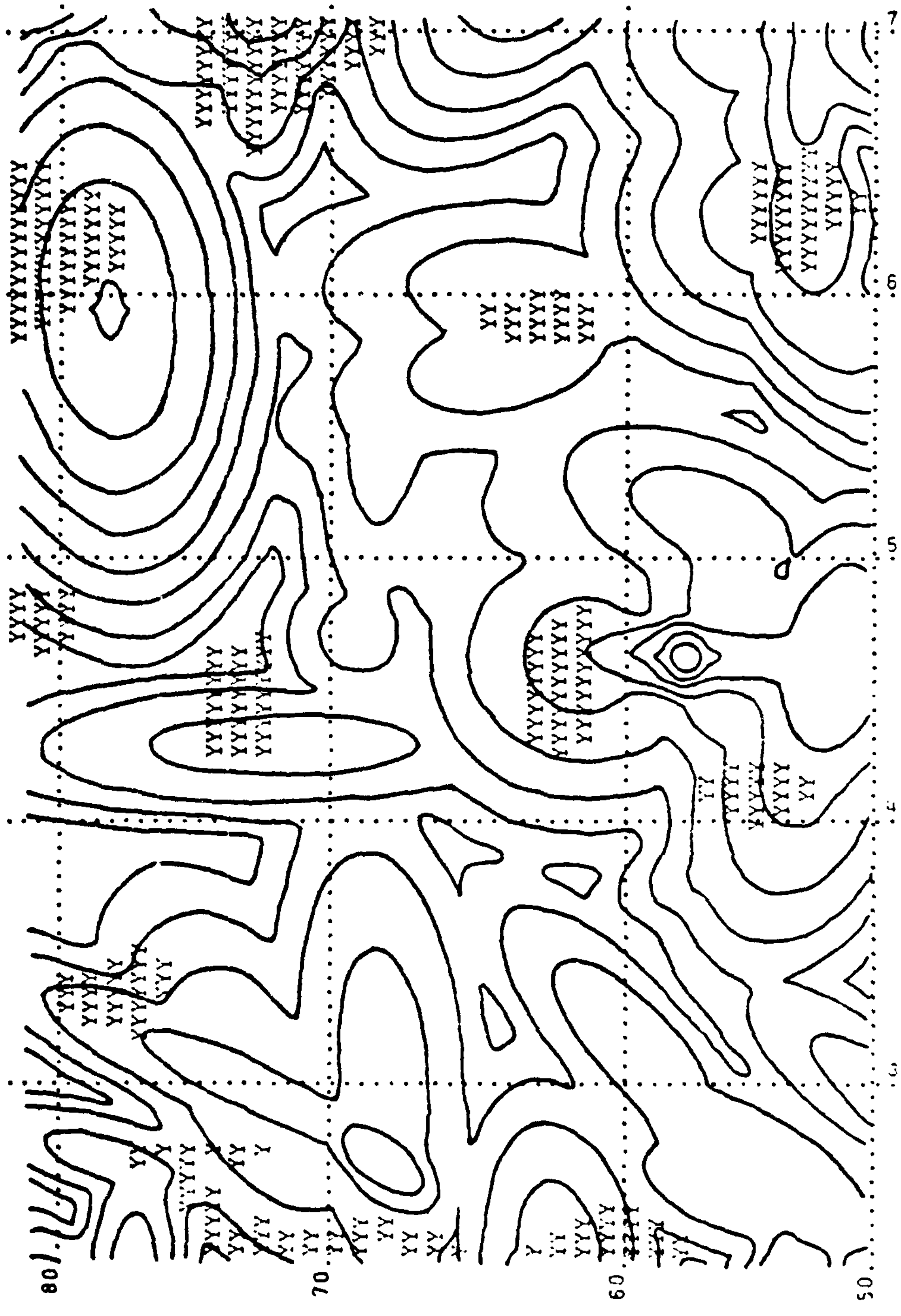


Figure A-2. Land Combat Terrain Model

## II. AVAILABLE OPTIONS

The model has been developed with a number of options available to the user to provide more model flexibility for the more experienced user. Each of these options, including user responsibilities, is discussed here with the input requirements for each being outlined in the next section.

### A. STOCHASTIC VS. DETERMINISTIC ATTRITION

The user has the option of using stochastic or deterministic attrition computation. Both methods utilize Lanchester aimed-fire equations; the difference between the two is the method of calculating the attrition-rate coefficients used in the Lanchester equations.

Deterministic attrition can be thought of as the expected value of attrition, and is implemented by using the Bonder-Farrell method of calculating the attrition-rate coefficient, $A_{ij}$. The stochastic method can be thought of as the randomization of attrition, and is implemented by using random deviates from a Beta Distribution in conjunction with the range of a target to generate individual attrition-rate coefficients for each unit at each time-step.

### B. VARIANT ATTACK ROUTES

The user has the option of providing variant aggressor force attack routes. The user can utilize the program's straight west-to-east routes, or can input desired altered routes for aggressor force units to follow. To select new routes, a user must input the number of nodes desired on

each of three routes, and the coordinates of each of these nodes. The program then will compute routes through each node. The nodes must be inputed in order from west to east, and should not create an angle between the west-to-east axis and the route direction that exceeds 45°.

## C. ALTERNATE DEFENSIVE POSITIONS

The user has the option of implementing alternative defensive unit locations. This option permits the user to add more realism to the model by allowing the defending units to withdraw to alternate positions when their primary positions become untenable (i.e., distance between opposing forces is too close). This breakpoint distance is determined and inputed by the user, and also is used as the distance for battle termination in the event that the battle reduces to close-in combat (i.e., hand-to-hand). The alternative to moving the defenders is to terminate the battle when the breakpoint distance is initially reached.

## D. BATTLE SUMMARY PRINT-OUT

The user has the option of limiting the printed output of the model. The user can receive a battle summary print-out at the completion of each 10-second time interval, or this information can be suppressed, printing out the results only after each phase of combat.

## III. REQUIRED INPUT

The small-unit amphibious operation combat model presented in this thesis has been provided with a blank data set (see Appendix D) which includes each variable of the model requiring input provided by the user, and space available following each variable for the user to place the desired variable value. However, the definition of each input variable may not be familiar to the first-time user of the program. Therefore, the following list of input variables and their definitions is provided as a quick reference for the user of the model.

### Ship-to-Shore Phase

| Input Variable | Definition |
|---|---|
| IPRINT | User option for selecting type of battle summary report desired:<br>0 - Each Time-Step<br>1 - End of Battle |
| SPDMAX | Maximum speed of LVA in the water. |
| SPDMIN | Minimum speed of LVA in the water. |
| HTMAX | Height of LVA above water at maximum speed. |
| HTMIN | Height of LVA above water at minimum speed. |
| WIDTH | Width of an LVA. |
| TENGMX | Tank maximum engagement range. |
| SENGMX | ATGM maximum engagement range. |
| SENGMN | ATGM minimum engagement range. |
| TARTM | Tank aim-reload time. |
| SARTM | ATGM aim-reload time. |

| Input Variable - | Definition |
|---|---|
| TVEL | Tank projectile velocity. |
| SVEL | ATGM projectile velocity. |
| TSIGV | Standard deviation error in the vertical axis for Tank fire. |
| TSIGH | Standard deviation error in the horizontal axis for Tank fire. |
| TMEANH | Bias error in the horizontal axis for Tank fire. |
| SSIGV | Standard deviation error in the vertical axis for ATGM fire. |
| DEFWTS | Defensive force tactical allocation weights. |
| WVINT(i) | Initial strength of assault wave I. |
| DINIT(i) | Initial strength of defensive Tank (I=1) and ATGM (I=2) units. |
| A(i) | Aggressor force attrition coefficients. |
| B(i) | Defensive force attrition coefficients. |
| WB(i) | Aimed-fire attrition-rate coefficients for defensive force Tank and ATGM units. |
| GAINL | Defensive force attrition level at which remaining defending forces withdraw and ground assault commences. |
| GAMMA | Aim-reload time suppression factor. |
| DELTA | Aiming error caused by the suppression factor of ATFFS |

The remaining portion of the input data refers to the terrain model developed by Professor James Hartman. It is suggested that this portion of the data set not be altered until the user has studied and fully understands the Hartman terrain model.

## Land Combat Phase

| Variable | Definition |
| --- | --- |
| ITRIT* | Input variable denoting whether attrition will be stochastic or deterministic:<br>0 - Stochastic<br>1 - Deterministic |
| DSEED** | Double precision seed used in the Beta Distribution Random Deviate Generator. |
| PP - QQ<br>PD - QD | Input parameters for the Beta Distribution Random Deviate Generator:<br>PP-QQ Aggressor force<br>PD-QD Defensive force |
| NBU | Number of defensive units. |
| NRU | Number of aggressor units. |
| RMINTK | Minimum effective range of an LVA weapon system. |
| RMAXTK | Maximum effective range of an LVA weapon system. |
| RMINTW | Minimum effective range of a defensive TOW weapon system. |
| RMAXTW | Maximum effective range of a defensive TOW weapon system. |
| IRTE | User option for selecting type of aggressor force attack routes:<br>0 - Program determined<br>1 - User determined |
| ISPD | Speed of aggressor force units:<br>1 - 9 MPH<br>2 - 12 "<br>3 - 15 "<br>4 - 18 " |
| XIC(i,j), YIC(i,j) | Coordinates of the $j^{th}$ interval endpoint of the route for Unit i. |
| N(i) | Number of nodes for aggressor route i. |

Note: *There are two ITRIT variables in the data set. The first ITRIT refers to the aggressor forces.

**There are two DSEED variables in the data set. The first DSEED refers to the aggressor forces.

| Variable | Definition |
|---|---|
| XLOC(i,j),YLOC(i,j) | Coordinates of node i for aggressor route i. |
| X(i),Y(i) | Location of defensive Unit i. |
| FL(i) | Force level of a defensive Unit i. |
| IPRDIR(i) | Principal direction of fire of defensive Unit i. |
| IALT | User option for selecting alternate defensive positions:<br>0 - Yes<br>1 - No |
| BREAK | Breakpoint distance between aggressor units and defensive units. |
| ITEM | Input variable denoting number of time-steps allowed for aggressor unit moves. |
| XA(i),YA(i) | Coordinates of alternate position for defensive Unit i. |
| P(i,j) | Probability of first round hit by Unit i in range band j. |
| PHH(i,j) | Probability of a hit following a hit by Unit i in range band j. |
| PHM(i,j) | Probability of a hit following a miss by Unit i in range band j. |
| PKH(i,j) | Probability of a kill given a hit by Unit i in range band j. |

# IV. EXPECTED OUTPUT

The small-unit amphibious operation combat model's output is designed to be self-explanatory. Each phase of the amphibious operation is reported in the output of the model. The output format for each phase will include an initial information section to provide the user with feedback concerning the operation of the model as read-in by the model from the user-supplied input data. This serves as a check and a record for the user to insure that the model was run according to the intended design of the user. Secondly, battle summary reports are provided at specific points of the battle depending upon the desires of the user as input by the user option variable IPRINT. An example of the model's output is displayed in Appendix F.

# V. ACCESSING AND EXECUTING THE MODEL

The prospective user who wishes to study the small-unit amphibious operation combat model must first contact Professor James Taylor of the Operations Research Department and obtain the user identification number and password for the disk space containing the model and its support programs.

## A. ACCESSING THE MODEL

Once the required information is obtained, the user should proceed to LOG ON to his OWN disk space entering the CMS mode of operation. Upon entering CMS, the following commands should be executed:

```
LINK TO (USER ID*) 191 AS 192 RR
PASSWORD
ACCESS 192 B/A
COPYFILE AMPHIB FORTRAN B = = A
COPYFILE SEA DATA B = = A
COPYFILE LAND DATA B = = A
COPYFILE  BSEA DATA B = = A
COPYFILE BLAND DATA B = = A
COPYFILE WAR EXEC B = = A
RELEASE 192 (DET
```

*Note: USER ID refers to the user id provided by Professor Taylor.

What is received on the user's disk is a copy of the following files:

1. The Small-Unit Amphibious Operation Combat Model (APPENDIX B).
2. A complete data set: SEA and LAND (APPENDIX C).
3. A blank data set: BSEA and BLAND (APPENDIX D).
4. The model's executive program: WAR (APPENDIX E).

B. EXECUTING THE MODEL

To execute the model utilizing the data set provided, the user must first compile the FORTRAN program, AMPHIB, by entering the following commands:

DEF STOR 1M

I CMS

FORTGI AMPHIB

Once the program is compiled, the user enters the name of the executive file WAR, which then executes the program and displays the listing file of output from the model, (i.e., AMPHIB1 LISTING (APPENDIX F)) in the BROWSE mode of XEDIT.

C. ALTERING THE DATA SET

The user may desire to invoke one of the available options provided, or alter specific elements of the existing data set to "play out" various combat scenarios. To alter the existing data set, the user first decides whether to alter the ship-to-shore phase of combat, or the land combat phase. Once this has been established, the user can simply XEDIT the appropriate data file, replacing the old input data with the new input data.

To construct an entirely new data set, the user should make use of the blank formatted data set provided. The user simply XEDIT's the

BSEA or BLAND data files, inputting new data by typing over the spaces provided. The variable names are listed in both of the data sets, as well as in Chapter III of this user's manual. The space provided in the blank data sets is designed to be compatible with the READ format statements of the program.

D. EXECUTING THE MODEL AFTER ALTERING DATA

If the user has just altered specific elements of the data set provided without altering file names, the user will once again enter the name of the executive file WAR, and enter the new data set file names where appropriate. Once this editing of the executive file has been accomplished, the user simply enters the executive file name WAR to execute the model again.

## VI. PROGRAM STRUCTURE

The small-unit amphibious operation combat model is a computerized model written in FORTRAN. It consists of a main program and 19 subroutines. To assist the user in understanding the operation of the model, a brief description of the function of each subroutine, as well as the functioning of the main program, is provided.

### A. MAIN PROGRAM

The main program serves as a director program for the model. It calls for the initialization of data for the ship-to-shore phase of combat, and then commences the execution of that phase of combat. The results of the ship-to-shore phase of combat as provided by subroutine SEA are then reviewed to determine if the land combat phase of combat should begin, or if the battle should be terminated. If the results warrant a continuation of the battle, the reason for continuation is printed and land combat is initiated.

### B. SUBROUTINES

There are 19 subroutines in the model. The function of each has been provided at the beginning of each subroutine in the coded program, and also is presented here for clarity.

#### 1. Subroutine SEA

This subroutine is the main driver program for the ship-to-shore phase of the amphibious operation. Its main purpose is to initialize key parameters, and to direct program flow in the ship-to-shore phase of combat.

2. Subroutine RKINT

This subroutine provides the interface between the EULER numerical integration routine (RKLDEG) and the subroutine ATTR which determines each unit's status as time progresses throughout the amphibious operation.

3. Subroutine ATTR

This subroutine determines the attrition rates and updates the status of each unit with respect to shore movement based upon the given state variable strengths, and implements this information into the attrition loss-rate computation.

4. Subroutine DTGTS

This subroutine determines the wave numbers that are to be engaged by the defensive Tank and ATGM units, based upon the engagement window criteria and LVA wave survivor force levels.

5. Subroutine DATAIN

This subroutine reads in all user-supplied information required by the ship-to-shore phase of the model.

6. Subroutine OUTPUT

This subroutine provides an input summary printout based upon the data received by subroutine DATAIN. A printout of dispersion data generated as a result of data supplied also is provided.

7. Subroutine PHIT

This subroutine computes the probability of a hit based upon the range, width, and height of a given target. The type of weapon being employed against the target then is taken into consideration for computing the specific probability of a hit.

8. Subroutine INTRP

This subroutine is a check to insure that the range of a target and the dispersion data are compatible for computing the probability of a hit in subroutine PHIT.

9. Subroutine RATE

Given the range and speed of a target, along with the type of weapon being used to fire upon the target, and the suppression factor the firer is being subjected to, subroutine RATE computes the rate of fire used against a particular target.

10. This is the primary subroutine of the land combat phase of the amphibious operation. Information required for the operation of the land combat phase is read-in and printed in a summary table for user review. The information provided by all other subroutines used in the land combat phase is used in this subroutine as input to the basic land combat algorithm.

11. Subroutine SETUP

This subroutine is used to read-in the terrain data and create parametric terrain. The terrain data will be used when computing line-of-sight between targets and observers, as well as providing a grid system for unit locations and movement.

12. Subroutine ROUTE

This subroutine computes the route of each aggressor unit when the user has selected the option of inputting aggressor routes. It calculates the coordinates of each interval endpoint along the route, making each interval length (distance moved during a ten-second time-step) the same. The interval length is determined by the speed the user has selected and inputted for the current battle.

13. Subroutine LAMBDA

This subroutine used in conjunction with the line-of-sight routine computes the detection rate (DETRAC) of target j by the observer i, given the percent of target visible (PCTVIS) to the observer.

14. Subroutine ELEV

This subroutine determines the terrain elevation for a given set of X, Y coordinates. This function is used in conjunction with the line-of-sight subroutine in computing a line-of-sight between observer and target.

15. Subroutine STOCH

This subroutine determines the attrition coefficients when a user has selected a stochastic attrition option. The calculation is a function of the original stochastically determined attrition coefficient, as well as a function of range.

16. Subroutine ETK

This subroutine computes the expected time for a given firer to kill a given target. The calculation is a function of range, time of flight for a round, and hit and kill probabilities for the firing weapon system. It is a number that is used in computation of the deterministic attrition coefficients.

17. Subroutine SORT

This subroutine is used to sort targets in ascending range order. This is used to determine the priority of a target for fire allocation.

18. Subroutine KOVER

This subroutine determines what portion of a particular target is covered by the terrain between the target and observer.

This number is used both in the detection of the target, and in the attrition computation.

19. Subroutine LOS

This subroutine was written by Professor James Hartman, Naval Postgraduate School. It computes a percent of a target visible to a particular observer, given the location coordinates of both.

## VII. DEFINITION OF VARIABLES IN COMPUTER PROGRAM

### A. VARIABLES USED IN THE SHIP-TO-SHORE PHASE

| | |
|---|---|
| A(i) | Aggressor force attrition coefficients. |
| ATFFS | Amphibious Task Force Fire Support. |
| B(i) | Defensive force attrition coefficients. |
| CDSURV(i) | Current strength of defensive Unit i:<br>1 - Tank<br>2 - ATGM |
| CSURVE(i) | Current strength of assault wave i. |
| DA(i) | Attrition rate for defensive Unit i due to the effects of ATFFS/TLF. |
| DEFWTS | Defensive Force Tactical Allocation Weights. |
| DELTA | Aiming error caused by the suppression factor of ATFFS. |
| DINIT(i) | Initial strength of defensive Unit i. |
| DS1 | That portion of the defensive force ATGM unit assigned to engaging the closer of two multiple waves in the ATGM engagement window. |
| DS2 | That portion of the defensive force ATGM unit assigned to engaging the farther of two multiple waves in the ATGM engagement window. |
| DT1 | That portion of the defensive force Tank unit assigned to engaging the closer of two multiple waves in the Tank engagement window. |
| DT2 | That portion of the defensive force Tank unit assigned to engaging the farther of two multiple waves in the Tank engagement window. |
| DT1PH | Hit probability of rounds fired by DT1 against the assault wave in its engagement window. |

| | |
|---|---|
| DT1ROF | Rate of fire utilized by DT1 against the assault wave in its engagement window. |
| GAINL | Defender attrition level at which remaining defending forces withdraw and land combat commences. |
| GALF | Denotes whether the landing force buildup is sufficient for land combat:<br>0 - Insufficient<br>1 - Sufficient |
| GAMMA | Aim-reload time suppression factor. |
| GATK | Denotes whether the landing force has initiated the land combat:<br>0 - Not started yet,<br>1 - Started already. |
| GATM | Time at which land combat commenced. |
| IL(i) | Denotes if wave i has reached the shore:<br>0 - Wave i not ashore,<br>1 - Wave i ashore. |
| IPRINT | Denotes whether the user desires battle summary at each time-step, or just a final summary:<br>0 - Battle summary printed after each time-step,<br>1 - Final battle summary only. |
| IWPN | Weapon-type code: Tank = 1, ATGM = 2. |
| IWSTAT(i) | Current status of assault wave i:<br>0 - Not engaged,<br>1 - Landed,<br>2 - Under fire by ATGM,<br>3 - Under fire by Tank,<br>4 - Under fire by both ATGM and Tank. |
| RD | Distance offshore at which waves initiate their transition. |
| RKSURV(i) | Concatenation of CSURV and CDSURV. |
| SA(i) | Attrition rate for wave i due to ATGM. |
| SARTM | ATGM aim-reload time. |
| SENG(i) | Wave number of the closer of two assault waves in the ATGM engagement window. |

| | |
|---|---|
| SENGMN | ATGM minimum engagement range. |
| SENGMX | ATGM maximum engagement range. |
| SRNG(i) | Firing range to wave SENG(i). |
| SSIGH | The standard deviation error in the horizontal axis for ATGM fire. |
| SSIGV | The standard deviation error in the vertical axis for ATGM fire. |
| SVEL | ATGM projectile velocity. |
| SWTS(i) | The proportion of the total defensive force ATGM strength to be allowed to engage wave SENG(i). |
| TA | Time first assault wave initiates its transition. |
| TA(i) | Attrition rate for assault wave i due to Tank fire. |
| TARTM | Tank aim-reload time. |
| TB | Time first assault wave completes its transition. |
| TBW | The interarrival time between waves arriving at the beach. |
| TFF | Time first assault wave reaches the beach. |
| TENG(i) | Wave number of the closer of two assault waves in the Tank engagement window. |
| TENGMX | Tank maximum engagement range. |
| TMEANH | The bias error in the horizontal axis for Tank fire. |
| TMEANV | The bias error in the vertical axis for Tank fire. |
| TRNG(i) | The firing range to assault wave TENG(i). |
| TSIGH | The standard deviation error in the horizontal axis for Tank fire. |
| TSIGV | The standard deviation error in the vertical axis for Tank fire. |

| | |
|---|---|
| TSURV | Total number of surviving LVA ashore at the current time. |
| TVEL | Tank projectile velocity. |
| TWTS(i) | The proportion of the total defensive force Tank strength to be allowed to engage wave TENG(i). |
| WB(i) | Aimed-fire attrition-rate coefficients for defensive force Tank and ATGM assets. |
| WID | Width of LVA. |
| WVINT(i) | Initial strength of assault wave i. |
| WVRNG | Firing range to assault wave i. |

B. VARIABLE USED IN THE LAND COMBAT PHASE

| | |
|---|---|
| ALPHA(i) | Initial attrition-rate coefficient for stochastic attrition option. |
| ANGH(i) | Orientation angle of the hill ellipse measured in degrees counter-clockwise from East to the major axis. |
| APOA(i,j) | The average proportion of the $j^{th}$ attacker of Unit i allocated to fire on Unit i. |
| AVD | Average distance. |
| AVSP | Average speed of moving aggressor units. |
| BASE | Overall terrain elevation above sea level. |
| BREAK | Breakpoint distance between aggressor units and defensive units. |
| DISMAX | Maximum distance allowed between aggressor units before the leading unit is delayed. |
| DIST | The straight-line distance between two movement nodes input by the user. |
| DST | The distance in meters to be moved each time-step by aggressor units. |
| ECC(i) | The eccentricity defined as the ratio of major axis length to minor axis length. |

| | |
|---|---|
| FL(i) | Force level of Unit i. |
| FO(i) | Initial force level of Unit i. |
| IALT | Denotes whether the user desires alternate defensive positions or not:<br>0 - Yes,<br>1 - No. |
| IC | Counts number of time units a defender has been moving. |
| IDIR | Direction of $j^{th}$ interval in $i^{th}$ route. |
| II(i) | Interval index for Unit i. |
| IITIME | Current time. |
| IMAX | Maximum number of time intervals allowed. |
| IMOVE | Number of time units a defender is allowed for moving to an alternate position. |
| IPRDIR(i) | Primary direction of fire for defensive Unit i. |
| IRAN | Range. |
| IRTE | Denotes whether user wants to input routes or not:<br>0 - Program determined routes,<br>1 - User determined routes. |
| ISE | A switch variable set to 1 when the defensive force ATGM unit initiates its fire. |
| ISECWD(i) | Width of search sector for defensive Unit i. |
| ISPD | Input variable to denote user's desired speed for aggressor force movement:<br>1 - 9 MPH,<br>2 - 12 MPH,<br>3 - 15 MPH,<br>4 - 18 MPH. |
| IT | Current time period. |
| ITE | A switch variable set to 1 when the defensive force Tank unit initiates its fire. |
| ITEM | Input variable denoting number of time-steps allowed for aggressor unit move. |

| | |
|---|---|
| ITIME | Current time, in seconds, of battle. |
| ITRIT | Input variable denoting whether attrition will be stochastic or deterministic:<br>0 - Stochastic,<br>1 - Deterministic. |
| IUSTAT(i) | Current status of Unit i:<br>0 - Alive, not firing,<br>1 - Alive and firing,<br>2 - Killed,<br>3 - Moving. |
| LVAFR | Firing rate for LVA weapon system. |
| LATOB | Indicator variable for one- or two-way LOS calls:<br>0 - Do not compute LOS from Unit A to Unit B,<br>1 - Compute LOS from Unit A to Unit B. |
| LISTH(i) | List of hill numbers for each grid square. |
| LOA(i,j) | The number of the $j^{th}$ target of Unit i. |
| LOST(i,j) | Denotes whether line-of-sight exists between Unit i and Unit j. |
| LOT(i,j) | The number of the $j^{th}$ target of Unit i. |
| LST | Index number for the first hill listed for grid square (i,j) in LISTH(i). |
| MVTDIR(i) | Movement direction of Unit i. |
| N(i) | Number of nodes inputted by user for route i. |
| NA(i) | Number of aggressors of Unit i. |
| NBU | Number of defensive force units. |
| NCVELS | Number of forest ellipses in terrain. |
| NF(i) | Number of time units a Unit i is allowed to fire at the same location. |
| NHL(i,j) | Number of hills in each grid square (i,j). |
| NHILLS | Number of different hills to be modeled. |
| NHTOT | Total number of hills modeled on battlefield. |

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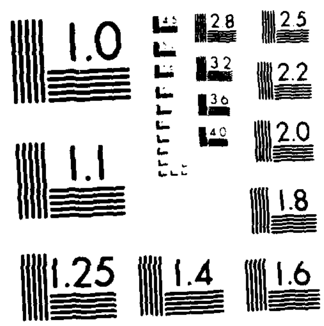


MICROCOPY RESOLUTION TEST CHART

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| | |
|---|---|
| NLOSC(i,j) | Number of continuous time-steps that LOS does not exist between Unit i and Unit j. |
| NOD | Number of time intervals Unit i delayed in movement. |
| NOI(i) | Number of intervals in the $i^{th}$ route. |
| NRU | Number of aggressor force units. |
| NT(i) | Number of targets of Unit i. |
| OFL(i) | Force level of Unit i during previous time-step. |
| P(i,j) | Probability of first round hit by Unit i in range band j. |
| PHH(i,j) | Probability of a hit following a hit by Unit i in range band j. |
| PHM(i,j) | Probability of a hit following a miss by Unit i in range band j. |
| PKH(i,j) | Probability of a kill given a hit by Unit i in range band j. |
| PM | The proportion of time a moving unit is searching for targets. |
| POA(i,j) | The proportion of the $j^{th}$ attacker of Unit i allocated to fire on Unit i. |
| POL(i) | Percent of Unit i lost during the current time-step. |
| PTT(i) | Proportion of surviving firepower allocated to the $i^{th}$ target if there are j targets available to be engaged. |
| RANGE | Current minimum distance between aggressors and defenders. |
| RKATTR | Vector containing the current attrition loss rates to be applied within the Euler integration routine. |
| RF | Detection rate reduction factor for a firing unit (in comparison to a non-firing unit). |
| RMINTK | Minimum effective range for an LVA mounted weapon system. |

| | |
|---|---|
| RMINTW | Minimum effective range for a TOW weapon system. |
| RMXTK | Maximum effective range for an LVA mounted weapon system. |
| RMXTW | Maximum effective range for a TOW weapon system. |
| ROF | Rate of fire. |
| ROT(i,j) | Range of the $j^{th}$ target of Unit i. |
| SIZETK | Size of LVA weapon system. |
| SIZETW | Size of TOW weapon system. |
| SPRD(i) | Measure of hill size which is defined to be the distance in meters measured along the major axis from hill center to the contour line which is 50 meters down from the peak. |
| SUMBO | Total defensive force level. |
| SUMRO | Total aggressor force level. |
| SUPFAC | Suppression factor. |
| TA(k) | Time to acquire a target for $k^{th}$ weapon system type (k = 1, 2). |
| TF1(k) | Time of flight to 1000m for $k^{th}$ weapon system type (k = 1, 2). |
| TF2(k) | Time of flight to 2000m for $k^{th}$ weapon system type (k = 1, 2). |
| TF3(k) | Time of flight to 3000m for $k^{th}$ weapon system type (k = 1, 2). |
| TH(k) | Time to fire a round following a hit for weapon system type (k = 1, 2). |
| TI(k) | Time to fire first round after target has been acquired for weapon system type (k = 1,2). |
| TM(k) | Time to fire round following a miss for weapon system type (k = 1, 2). |
| TMACI,TMACJ | Elevation of Unit i and Unit j in LOS model. |
| TOWFR | Firing rate for TOW weapon system. |

| | |
|---|---|
| TPOL(i) | Total percentage of lost since battle began for Unit i. |
| VISFR(i,j) | The fraction of Unit i as seen by Unit j. |
| VISFRA | Fraction of Unit A as seen by Unit B. |
| VISFRB | Fraction of Unit B as seen by Unit A. |
| X(i),Y(i) | Coordinates of Unit i. |
| XA(i),YA(i) | Coordinates of alternate position for defensive Unit i. |
| XC(i),YC(i) | Coordinates of center of hill i. |
| XIC(i,j) YIC(i,j) | Coordinates of the $j^{th}$ interval endpoint of the route for Unit i. |
| XL,YL | Distance added to previous interval endpoint for vehicle to move DST during a time-step. |
| XLOC(i,j) YLOC(i,j) | Coordinates of the $j^{th}$ node inputted by the user for the route of Unit i. |

## APPENDIX B

## COMPUTER PROGRAM

## for the

## SMALL-UNIT AMPHIBIOUS OPERATION COMBAT MODEL

The small-unit amphibious operation combat model is a computerized model written in FORTRAN. It consists of a main program and 19 subroutines. It was designed to serve as a reference to itself in order that the reader would not be forced to refer to various manuals outside of the program each time an explanation of the functioning of a particular aspect of the program was desired. A listing of the computer program follows.

```
C      THIS PROGRAM IS A SMALL-UNIT AMPHIBIOUS OPERATION COMBAT MODEL
C      UTILIZING LANCHESTER-TYPE EQUATIONS TO COMPUTE ATTRITION.
C      IT CONSISTS OF TWO BASIC PHASES, THE FIRST BEING THE SHIP-TO-SHORE
C      COMBAT PHASE, AND THE SECOND BEING THE LAND COMBAT PHASE.
C
C         ***** SHIP-TO-SHORE PHASE COMMON BLOCK VARIABLES *****
C
       COMMON /AMPH/IL(5),WB(2),A(2),B(2),ITE,ISE,RD,WVINT(5),WID,
     *TBW,DINIT(2),GAINL,IWSTAT(5)
       COMMON /ENGR/ SPDMAX,SPDMIN,HTMAX,HTMIN,TTS,TAA,TB,TFF
       COMMON /DISPER/TSIGV(6,2),TSIGH(6,2),TMEANH(6,2),
     *SSIGV(7,2),SSIGH(7,2)
       COMMON /CEF/TENGMX,SENGMX,SENGMN,TARTM,SARTM,TVEL,
     *SVEL,DEFWTS(2)
       COMMON /SUPEFT/GAMMA,DELTA
       COMMON /IOUT/TSURV,IPRINT
C
C           ***** LAND COMBAT PHASE COMMON BLOCK VARIABLES *****
C
       COMMON /GRP1/ IPRDIR(6),ISECWD(6),MVTDIR(6),X(6),Y(6),SPD(6)
       COMMON /GRP2/ TA(2),T1(2),TH(2),TM(2),TF1(2),TF2(2),TF3(2),
     *P(2,6),PHH(2,6),PHM(2,6),PKH(2,6),TF(2)
       COMMON /GRP3/ NBU,NRU,FL(6),FC(6),NOI(3),XIC(3,200),YIC(3,200),
     *IDIR(3,200),AVSF,ISPC
     *,IUSTAT(6),II(6),LOST(6,6),VISFRA,VISFRB,SIZETK,
     *SIZETW,NT(6),NF(6),SRF,DISMAX,
     *NLDSC(6,6),VISFR(6,6),RMINTK,RMXTK,RMINTW,RMXTW,OP,TOWER,LVAFR,
     *PTT(3,3),RF,PCA(6,6),APCA(6,6),LOA(6,6),NA(6),OFL(6),PCL(6)
       COMMON /GRP4/ TPCL(6),CLOC(6,6),Q(6,6)
       COMMON /GRP5/ LCT(6,6),ROT(6,6)
       COMMON /HILLS/ XC(100),YC(100),PEAK(100),ANGH(100),SPRD(100)
       COMMON /HILLS/ ECC(100),PXX(100),PYY(100),PXY(100),BASE
       COMMON /HILLS/ NHILLS
       COMMON /COVER/ CXC(150),CYC(150),CPEAK(150),CPXX(150),CPYY(150)
       COMMON /COVER/ CPXY(150),NCVELS
       COMMON /CCUNTR/ KH,KHW,KV,KN,KGRS,KELL,KINT
       COMMON /GRID/ LST(5,4),NHL(5,4),LISTH(150),KHREP(150),KTREP
       COMMON /GRID/ LSTC(5,4),NC(5,4),LISTC(400),KCREP(150)
       COMMON /GRP6/ ALPHA(6)
       COMMON /GRP7/ XA(6),YA(6),IMOVE(6)
C
C                          ***** MAIN DRIVER PROGRAM *****
C
       GATM=0.
       GATK=0.
C ***  INITIALIZE DATA FOR SHIP-TO-SHORE PHASE
       CALL DATAIN
C
       CALL SETUP
C ***  CONDUCT SHIP-TO-SHORE COMBAT PHASE
       CALL SEA(GATM,GATK)
       IF(GATK.NE.0.) GO TO 5
          WRITE(6,600)
       STOP
     5 IF(GATK-2.0) 10,20,30
    10    WRITE(6,610)
             GO TO 40
    20    WRITE(6,620)
             GO TO 40
    30    WRITE(6,630)
    40    WRITE(6,640) GATM
C ***  CONDUCT LAND COMBAT PHASE
       CALL GROUND(GATM,TSURV,IPRINT,TTS)
C
C
   600 FORMAT(1X,'TOTAL LANDED LANDING FORCE STRENGTH IS INSUFFICIENT',
      *' FOR GROUND ATTACK')
   610 FORMAT(1X,'LAND COMBAT STARTS WHILE SHORE COMBAT IS GOING ON')
   620 FORMAT(1X,'LAND COMBAT STARTS AFTER DEFENDER BREAKS CONTACT')
   630 FORMAT(1X,'LAND COMBAT STARTS AFTER ALL WAVES LANDED')
   640 FORMAT(/1X,'LAND COMBAT ATTACK TIME =',F6.1,' SECONDS')
       STOP
```

```
      END
C
      SUBROUTINE SEA(GATM,GATK)
C *** SUBROUTINE IS THE MAIN DRIVER PROGRAM FOR THE SHIP-TO-SHORE
C     PHASE OF THE AMPHIBIOUS OPERATION.  ITS MAIN PURPOSE IS TO
C     INITIALIZE KEY PARAMETERS AND TO DIRECT PROGRAM FLOW FOR THE
C     SHIP-TO-SHORE PHASE OF COMBAT
C
      COMMON /AMPH/IL(5),WB(2),A(2),B(2),ITE,ISE,RD,WVINT(5),WID,
     *TBW,DINIT(2),GAINL,IWSTAT(5)
      COMMON /ENGR/ SPDMAX,SPDMIN,HTMAX,HTMIN,TTS,TAA,TB,TFF
C
      CALL OUTFLT
      IRD=500
      ITBW=120
      RD=1.0*IRD
      TBW=1.0*ITBW
      TINT=0.0
C
C *** COMPUTATION OF FIRST WAVE TIME PARAMETERS
C        TA-TIME FIRST WAVE INITIATES TRANSITION
C        TB-TIME FIRST WAVE COMPLETES TRANSITION
C        TFF-TIME FIRST WAVE REACHES THE BEACH
C
      TAA=(5000.-RD)/SPDMAX
      TB=TAA+TTS
      TFF=TB+(RD-(0.5*(SPDMAX-SPDMIN)*TTS)-150.)/SPDMIN
      DEL=10.
C     WRITE(6,600) RD,TBW
C 600 FORMAT(/,1X,'ITERATION INITIATED...RD=',F10.3,1X,'TBW=
C    *',F10.3)
      CALL RKINT(DEL,TINT,N,GATM,GATK)
      RETURN
      END
C
C
C
      SUBROUTINE RKINT(H,TI,N,GATM,GATK)
C
C *** SUBROUTINE RKINT PROVIDES THE INTERFACE BETWEEN
C     THE EULER NUMERICAL INTEGRATION ROUTINE(RKLDEQ)
C     AND THE SUBROUTINE ATTR WHICH DETERMINES EACH
C     UNIT'S STATUS AS TIME PROGRESSES THROUGHOUT THE
C     AMPHIBIOUS OPERATION
C
      COMMON /AMPH/IL(5),WB(2),A(2),B(2),ITE,ISE,RD,WVINT(5),WID,
     *TBW,DINIT(2),GAINL,IWSTAT(5)
      COMMON /IOUT/TSURV,IPRINT
      DIMENSION CSURV(5),CDSURV(2),TA(5),SA(5),DA(2)
      DIMENSION  RKSURV(7),RKATTR(7),TATTR(200,12),TIME(200)
C
C                    ***** VARIABLE DEFINITIONS *****
C     IMAX - MAXIMUM ALLOWABEL NUMBER OF TIME INTERVALS
C     IL(I) - A SWITCH VARIABLE WHOSE ELEMENT I IS SET TO 1 WHEN
C             WAVE I ARRIVES AT THE BEACH
C     ISE - A SWITCH VARIABLES SET TO 1 WHEN THE DEF.ATGM
C           UNIT INITIATES ITS FIRE
C     IT - CURRENT TIME PERIOD
C     ITE - A SWITCH VARIABLES SET TO 1 WHEN THE DEF.TANK
C           UNIT INITIATES ITS FIRE
C     T - CURRENT TIME
C     TSURV - TOTAL NUMBER OF SURVIVING LVA AT THE CURRENT TIME
C
C                  ***** STATE VARIABLE DEFINITIONS *****
C     CDSURV(I) - CURRENT STRENGTH OF DEFENSIVE FORCE I
C                 I = 1          TANK
C                 I = 2          ATGM
C     CSURV(I) - CURRENT STRENGTH OF ASSAULT WAVE I
C     DINIT(I) - INITIAL STRENGTH OF DEFENSIVE FORCE I
C     RKSURV(I) - CONCATENATION OF CSURV AND CDSURV
C     WVINT(I) - INITIAL STRENGTH OF WAVE I
C
```

```
      IX = 28543
      GALF=0.
      IMAX=199
      ITE=0
      ISE=0
      TSURV=0.
      TIME(I)=C.
      T=TI
      DO 10 I=1,5
         CSURV(I)=WVINT(I)
         TSURV=TSURV+CSURV(I)
         IL(I)=C
         IWSTAT(I)=0
   10 CONTINUE
      DO 15 I=1,2
         CDSURV(I)=DINIT(I)
   15 CONTINUE
      DO 20 J=1,12
   20 TATTR(1,J)=0.
      IT=1
      DO 25 I=1,5
   25 RKSURV(I)=CSURV(I)
      RKSURV(6)=CSURV(1)
      RKSURV(7)=CSURV(2)
      DO 30 I=1,7
   30 RKATTR(I)=C.
      NT=0
  120 CALL ATTR(T,CSURV,CDSURV,TA,SA,DA,GALF,GATK,GATM,IX)
C
C              ***** STATE VARIABLE DEFINITIONS *****
C     DA(I) - ATTRITION RATE FOR DEFENSIVE UNIT I DUE TO
C             THE EFFECTS OF ATFFS/TLF
C     SA(I) - ATTRITION RATE FOR WAVE I DUE TO ATGM
C     TA(I) - ATTRITION RATE FOR WAVE I DUE TO TANKS
C
C     RKATTR(I) IS A VECTOR CONTAINING THE CURRENT ATTRITION
C               LOSS RATES TO BE APPLIED WITHIN THE EULER
C               INTEGRATION ROUTINE TO THE STATE VARIABLES.
C                  I=1,5      LVA WAVES 1-5
C                  I=6        DT
C                  I=7        DS
C
      IX = IX + 7
      IF(IL(1).EQ.99) GO TO 130
         DO 40 I=1,5
            RKSURV(I)=CSURV(I)
   40    RKATTR(I)=(TA(I)+SA(I))*(-1.0)
      DO 45 I=1,2
         RKSURV(I+5)=CDSURV(I)
   45 RKATTR(I+5)=-1.0*DA(I)
      S=RKLDEQ(7,RKSURV,RKATTR,T,H,NT)
               LSINK = 1
      DO 50 I=1,5
         IF (LSINK.EQ.0) GO TO 46
            CSURV(I) = CSURV(I) + RKATTR(I)
            GO TO 50
   46    CSURV(I) = RKSURV(I)
   50 CONTINUE
      DO 55 I=1,2
         CDSURV(I)=RKSURV(I+5)
   55 CONTINUE
      IF(S-1.) 110,120,130
  110    WRITE(6,600)
         STOP
  130 CONTINUE
      IT=IT+1
      TSURV=0.
      DO 65 L=1,5
   65 TSURV=TSURV+CSURV(L)
      IF(TSURV.LE.C.) TSURV=0.
         TIME(IT)=T
      IF(IPRINT.EQ.1) GO TO 999
```

```
C *** PRINT RESULT OF SHIP-TO-SHORE MOVEMENT AFTER EACH TIME STEP
      WRITE(6,610) T
      WRITE(6,620)
      DO 70 I=1,4
         PLOST=1.-CSURV(I)/WVINT(I)
         WRITE(6,630) I,CSURV(I),IWSTAT(I),PLOST
   70 CONTINUE
      PLOST=1.-CSURV(5)/WVINT(5)
      WRITE(6,640) CSURV(5),IWSTAT(5),PLOST,TSURV
      PLOST=1.-CDSURV(1)/DINIT(1)
      WRITE(6,650) CDSURV(1),PLOST
      PLOST=1.-CDSURV(2)/DINIT(2)
      TASURV=CDSURV(1)+CDSURV(2)
      WRITE(6,660) CDSURV(2),PLOST,TASURV
  999 CONTINUE
C
C *** DETERMINE R: THE FIRING RANGE TO THE LAST INCOMING ASSAULT WAVE.
C
      R=RNG(T-4.*TBW)
C *** DETERMINE IF ALL WAVES LANDED AND LAND COMBAT STARTED
C     NOTE: THE MODEL IS TERMINATED IF:
C              1.  THE FIRING RANGE TO THE LAST ASSAULT WAVE IS LESS
C                  THAN 75 METERS.
C              2.  THE DEFENSIVE BREAKPOINT HAS BEEN REACHED
C              3.  THE MAXIMUM NUMBER OF ITERATIONS HAS BEEN EXCEEDED
C
      IF(R.LT.75.) GO TO 200
         IF(IT.GT.IMAX) GO TO 200
            IF(IL(1).EQ.99) GO TO 200
               GO TO 120
  200 N=IT
C *** PRINT RESULT OF THE SHIP-TO-SHORE COMBAT PHASE
      WRITE(6,610) T
      WRITE(6,620)
      DO 90 I=1,4
         PLOST=1.-CSURV(I)/WVINT(I)
         WRITE(6,630) I,CSURV(I),IWSTAT(I),PLOST
   90 CONTINUE
      PLOST=1.-CSURV(5)/WVINT(5)
      WRITE(6,640) CSURV(5),IWSTAT(5),PLOST,TSURV
      PLOST=1.-CDSURV(1)/DINIT(1)
      WRITE(6,650) CDSURV(1),PLOST
      PLOST=1.-CDSURV(2)/DINIT(2)
      TASURV=CDSURV(1)+CDSURV(2)
      WRITE(6,660) CDSURV(2),PLOST,TASURV
      WRITE(6,670) TSURV
      IF(GATK.GE.1.) GO TO 9999
         IF(TSURV.LT.9.) GO TO 9999
            GATK=3.
            GATM=T
 9999 CONTINUE
  600    FORMAT(1X,'ERROR..S.NE.1.OR.2')
  610 FORMAT(///1X,'TIME=',F6.1,1X,'SECONDS'//)
  620 FORMAT(1X,'WAVE',2X,'FORCE LEVEL',2X,'STATUS',2X,'LOST-PCT',
     *2X,'TOTAL SURVIVING')
  630    FORMAT(3X,I1,3X,F10.4,5X,I1,5X,F8.3)
  640 FORMAT(3X,'5',3X,F10.4,5X,I1,5X,F8.3,7X,F5.2)
  650 FORMAT(1X,'TANK',2X,F10.4,11X,F8.3)
  660 FORMAT(1X,'ATGM',2X,F10.4,11X,F8.3,7X,F5.2)
  670 FORMAT(1X,'FINAL LVA SURVIVORS ASHORE= ',F10.3)
      RETURN
      END
C
C
C
      FUNCTION RKLDEQ(N,Y,F,X,H,NT)
      DIMENSION Y(1),F(1),Q(25)
      NT=NT+1
      GO TO (1,2,3,4),NT
    1 H1=H
      AA=H1/4.0
      DO 11 J=1,N
```

```
   11 Q(J)=0.
      X=X+AA
      GO TO 5
    2 X=X+AA
      GO TO 5
    3 X=X+AA
      GO TO 5
    4 DO 6 L=1,N
    6 Y(L)=Y(L)+AA*F(L)
      NT=0
      X=X+AA
      RKLDEQ=2.
      GO TO 8
    5 DO 7 I=1,N
    7 Y(I)=Y(I)+AA*F(I)
      RKLDEQ=1.0
    8 RETURN
      END
C
C
C
      SUBROUTINE ATTR(T,CSURV,DSURV,TA,SA,CA,GALF,GATK,GATM,IX)
C
C *** GIVEN THE CURRENT TIME AND STATE VARIABLE STRENGTHS,
C     SUBROUTINE ATTR DETERMINES THE ATTRITION RATES AND UPDATES
C     THE STATUS OF EACH UNIT WITH RESPECT TO SHORE MOVEMENT
C     AND IMPLEMENTS THIS INFORMATION INTO THE ATTRITION LOSS RATE
C     COMPUTATION.
C              ***** STATE VARIABLE DEFINITIONS *****
C     CA(I) - CURRENT ATTRITION LOSS RATE FOR DEF. FORCE I DUE TO
C             ATFFS(AMPHIBIOUS TASK FORCE FIRE SUPPORT)/TLF EFFECTS
C     IL(I) - WHEN EQUAL TO 99 INDICATES THE DEFENSIVE BREAKPOINT
C             HAS BEEN REACHED
C     SA(I) - CURRENT ATTRITION LOSS RATE FOR WAVE I DUE TO ATGM FIRE
C     TA(I) - CURRENT ATTRITION LOSS RATE FOR WAVE I DUE TO TANK FIRE
C
C
      COMMON /AMPH/IL(5),WB(2),A(2),B(2),ITE,ISE,RD,WVINT(5),WID,
     *TEW,DINIT(2),GAINL,IWSTAT(5)
      COMMON /DEF/TENGMX,SENGMX,SENGMN,TARTM,SARTM,TVEL,
     *SVEL,DEFWTS(2)
      INTEGER TENG(2),SENG(2)
      DIMENSION TRNG(2),TWTS(2),SRNG(2),DSURV(2),SWTS(2),
     *CSURV(5),TA(5),SA(5),CA(2),ASX(20)
C
C
      LSINK = 1
C
C
      DO 10 I=1,5
         TA(I)=0.
         SA(I)=0.
   10 CONTINUE
C
C                    ***** VARIABLE DEFINITIONS ******
C     DT1 - THAT PORTION OF THE DT UNIT ASSIGNED TO ENGAGING THE CLOSER
C           OF TWO MULTIPLE WAVES IN THE TANK ENGAGEMENT WINDOW
C
C     DT2 - THAT PORTION OF THE DT UNIT ASSIGNED TO ENGAGING THE FARTHER
C           OF TWO MULTIPLE WAVES IN THE TANK ENGAGEMENT WINDOW
C
C     DS1 - THAT PORTION OF THE DS UNIT ASSIGNED TO ENGAGING THE CLOSER
C           OF TWO MULTIPLE WAVES IN THE ATGM ENGAGEMENT WINDOW
C
C     DS2 - THAT PORTION OF THE DS UNIT ASSIGNED TO ENGAGING THE FARTHER
C           OF TWO MULTIPLE WAVES IN THE ATGM ENGAGEMENT WINDOW
C
      DS1=0.
      DS2=0.
      DT1=0.
      DT2=0.
      FAC=1.0
```

```
C
C *** DETERMINE IF PART OF LANDING FORCE ADVANCE TO ATTACK INLAND
C     KEY TERRAIN
C
      IF(GATK.EQ.1.0) GO TO 15
         IF(GALF.EQ.1.0.AND.(DSURV(1)+DSURV(2)).LE.GAINL*(DINIT(1)
     *+DINIT(2))) GATM=T
            IF(GALF.EQ.1.0.AND.(DSURV(1)+DSURV(2)).LE.GAINL*(DINIT(1)
     *+DINIT(2))) GATK=1.0
C
C *** DETERMINE IF DEF. BREAKPOINT HAS BEEN REACHED
C
   15 IF((DSURV(1)+DSURV(2)).LT.0.3*(DINIT(1)+DINIT(2))) GO TO 20
C
C *** DETERINE ATTRITION RATE ON DEFENSIVE FORCES BY ATFFS
C     BASED UPON AREA OR AIMED FIRE STATUS
C             WVRNG = FIRING RANGE TO AN ASSAULT WAVE
C
      DA(1)=B(1)
      DA(2)=B(2)
      IF(ITE.EQ.0) DA(1)=A(1)*DSURV(1)
         IF(ISE.EQ.0) DA(2)=A(2)*DSURV(2)
         GO TO 40
   20 DSURV(1)=0.
      DSURV(2)=0.
      DA(1)=0.
      DA(2)=0.
      IF(GATK.EQ.1.) GO TO 35
         GAT=T
C
C *** DETERMINE IF DEF.BREAKPOINT HAS BEEN REACHED BEFORE SUFFICIENT
C     LANDING FORCE IS BUILT UP ON THE SHORE FOR INLAND ATTACK
C
   25 DO 30 I=1,5
         WVRNG=RNG(GAT-TBW*(I-1))
         IF(WVRNG.LT.75.) IL(I)=1
            IF(IL(I).EQ.1) TLF=TLF+CSURV(I)
   30 CONTINUE
      GAT=GAT+10.
      IF(TLF.LT.9.0.AND.IL(5).EQ.1) RETURN
         IF(TLF.LT.9.0.AND.IL(5).NE.1) GO TO 25
            GATK=2.
            GALF=1.
            GATM=GAT
            WRITE(6,610) GATM
  610       FORMAT(/,1X,'LAND COMBAT INITIATED  TIME=',F7.1,' SECONDS')
   35       IL(1)=99
            WRITE(6,620) T
  620       FORMAT(1X,'BREAKPOINT REACHED AT TIME =',F7.1,' SECONDS')
            RETURN
C
C *** SUBROUTINE DTGTS DETERMINES THE FIRING STATUS FOR THE
C     TWO DEFENSIVE UNITS.
C
   40 CALL DTGTS(T,TENG,TRNG,TWTS,SENG,SRNG,SWTS,CSURV)
C
C           ***** STATE VARIABLE DEFINITIONS *****
C     TENG(1) - THE WAVE NUMBER OF THE CLOSER OF TWO
C               WAVES IN THE TANK ENGAGEMENT WINDOW
C     TRNG(1) - THE FIRING RANGE TO WAVE TENG(1)
C     TWTS(1) - THE PROPORTION OF THE TOTAL DT STRENGTH
C               TO BE ALLOCATED TO ENGAGING TENG(1)
C     TENG(2) - THE WAVE NUMBER OF THE FARTHER OF TWO
C               WAVES IN THE TANK ENGAGEMENT WINDOW
C     TRNG(2) - SIMILAR INTERPRETATION AS TRNG(1)
C     TWTS(2) - SIMILAR INTERPRETATION AS TWTS(1)
C     SENG(1) - THE WAVE NUMBER OF THE CLOSER OF TWO
C               WAVES IN THE ATGM ENGAGEMENT WINDOW
C     SRNG(1) - FIRING RANGE TO WAVE SENG(1)
C     SWTS(1) - THE PROPORTION OF THE TOTAL DS STRENGTH
C               TO BE ALLOCATED TO ENGAGING SENG(1)
C     SENG(2) - THE WAVE NUMBER OF THE FARTHER OF TWO
```

```
C                 WAVES IN THE ATGM ENGAGEMENT WINDOW
C       SRNG(2) - SIMILAR INTERPRETATION AS SRNG(1)
C       SWTS(2) - SIMILAR INTERPRETATION AS SWTS(1)
C
C *** DETERMINE THE CUMULATIVE NUMBER OF SURVIVING LVA'S
C     THAT HAVE REACHED THE BEACH - TLF
C
      TLF=0.
      DO 45 J=1,5
         IF(IL(J).EQ.1) TLF=TLF+CSURV(J)
   45 CONTINUE
C
C *** DETERMINE IF TLF BUILT UP IS SUFFICENT FOR LAND COMBAT
C
      IF(TLF.GE.9.) GALF=1.
         IF(GATK.EQ.1.) TLF=TLF-9.
C
C *** ALLOCATE THE FORCE STRENGTH OF TLF BETWEEN THE TWO
C     DEFENSIVE FORCE UNITS
C
      DSUM=DSURV(1)+DSURV(2)
      TLF1=(DSURV(1)/DSUM)*TLF
      TLF2=(DSURV(2)/DSUM)*TLF
C
C *** ADD TO DA1 AND DA2 THE ATTRITION LOSS RATE DUE
C     TO THE EFFECTS OF TLF1 AND TLF2
C
      DA(1)=DA(1)+TLF1*W8(1)
      DA(2)=DA(2)+TLF2*W8(2)
      IF(DSURV(1).LE.0.0) DA(1)=0.
         IF(DSURV(2).LE.0.0) DA(2)=0.0
            ICA = 1
            N = 20
            MUL = 1
            ISCRT = 0
            CALL LRND(IX,ASX,N,MUL,ISCRT)
C
C *** DETERMINE IF THERE EXISTS AN INCOMING WAVE IN THE
C     TANK ENGAGEMENT WINDOW (I.E. TENG(1).NE.0)
C
      IF(TENG(1).EQ.0.) GO TO 100
         ITE=1
C
C *** DETERMINE THE TIME SINCE WAVE TENG(1) CROSSED THE
C     5000. METER OFFSHORE MARK -T1
C
      T1=T-TBW*(TENG(1)-1)
      DT1=TWTS(1)*DSURV(1)
      FAC=1.
C
C *** DETERMINE THE SUPPRESSION EFFECT TO BE IMPOSED
C     ON THE DT UNIT BASED ON THE ATTRITION LOSS RATE
C     CURRENTLY IN EFFECT
C              SUPFAC = ATFFS SUPRESSION FACTOR
C
      SUPFAC=DA(1)
C
      CALL RATE(TRNG(1),SPD(T1),1,SUPFAC,DT1ROF)
C ***    DT1ROF - RATE OF FIRE UTILIZED BY DT1 AGAINST WAVE TENG(1)
      CALL PHIT(TRNG(1),WID,HT(T1),1,SUPFAC,DT1PH)
C ***    DT1PH - HIT PROBABILITY OF ROUNDS FIRED BY DT1
C                AGAINST WAVE TENG(1)
C
C *** DETERMINE THE ATTRITION LOSS RATE FOR WAVE TENG(1)
C     DUE TO DT1 FIRES
C
      TA(TENG(1))=DT1PH*DT1ROF*DT1
      IF (LSINK.EQ.0) GO TO 55
         IF (ASX(ICA).GT.TA(TENG(1))) GO TO 50
            TA(TENG(1)) = 1.0
            GO TO 55
50       TA(TENG(1)) = 0.0
```

```
55   ICA = ICA + 1
C
C *** DETERMINE IF THERE IS A SECOND INCOMING WAVE THAT
C     IS IN THE TANK ENGAGEMENT WINDOW, IF THERE IS THE
C     ATTRITION RATE COMPUTATIONS ARE SIMILAR IN FORM
C     TO THOSE PREVIOUSLY PERFORMED FOR THE CLOSER WAVE
C
      IF(TENG(2).EQ.0) GO TO 100
         T2=T-TBW*(TENG(2)-1)
         DT2=TWTS(2)*DSURV(1)
         CALL RATE(TRNG(2),SPD(T2),1,SUPFAC,DT2ROF)
         CALL PHIT(TRNG(2),WID,HT(T2),1,SUPFAC,DT2PH)
         TA(TENG(2))=DT2PH*DT2ROF*DT2
         IF(LSINK.EQ.0) GO TO 65
            IF(ASX(ICA).GT.TA(TENG(2))) GO TO 60
               TA(TENG(2)) = 1.0
               GO TO 65
60          TA(TENG(2)) = 0.0
65   ICA = ICA + 1
C
C *** DETERINE IF THERE EXISTS AN INCOMING WAVE IN THE ATGM
C     ENGAGEMENT WINDOW, IF THERE IS, DETERMINE THE ATTRITION
C     EFFECTS AGAINST THAT WAVE DUE TO ATGM THE ATTRITION
C     RATE COMPUTATION ARE SIMILAR IN FORM TO THOSE FOR THE
C     EFFECTS DUE THE TANK FIRE.
C
100  IF(SENG(1).EQ.0) GO TO 200
         ISE=1
         S1=T-TBW*(SENG(1)-1)
         DS1=SWTS(1)*DSURV(2)
         SUPFAC=DA(2)
         CALL RATE(SRNG(1),SPD(S1),2,SUPFAC,DS1ROF)
         CALL PHIT(SRNG(1),WID,HT(T1),2,SUPFAC,DS1PH)
         SA(SENG(1))=DS1PH*DS1ROF*DS1
         IF(LSINK.EQ.0) GO TO 75
            IF(ASX(ICA).GT.SA(SENG(1))) GO TO 70
               SA(SENG(1)) = 1.0
               GO TO 75
70          SA(SENG(1)) = 0.0
75       ICA = ICA + 1
      IF(SENG(2).EQ.0) GO TO 200
         S2=T-TBW*(SENG(2)-1)
         DS2=SWTS(2)*DSURV(2)
         CALL RATE(SRNG(2),SPD(S2),1,SUPFAC,DS2ROF)
         CALL PHIT(SRNG(2),WID,HT(S2),2,SUPFAC,DS2PH)
         SA(SENG(2))=DS2PH*DS2ROF*DS2
         IF(LSINK.EQ.0) GO TO 85
            IF(ASX(ICA).GT.SA(SENG(2))) GO TO 80
               SA(SENG(2)) = 1.0
               GO TO 85
80          SA(SENG(2)) = 0.0
85       ICA = ICA + 1
200  RETURN
      END
C
C
C
      SUBROUTINE DTGTS(T,TENG,TRNG,TWTS,SENG,SRNG,SWTS,CSURV)
C
C *** GIVEN THE CURRENT TIME AND LVA WAVE SURVIVOR POPULATIONS,
C     SUBROUTINE DTGTS DETERMINES THE WAVE NUMBERS THAT ARE
C     TO BE ENGAGED BY DEFENSIVE TANK AND ATGM UNITS BASED
C     ON THE ENGEMENT WINDOW CRITERIA
C
      COMMON /AMPH/IL(5),WB(2),A(2),B(2),ITE,ISE,RD,WVINT(5),WID,
     *TBW,DINIT(2),GAINL,IWSTAT(5)
      COMMON /DEF/TENGMX,SENGMX,SENGMN,TARTM,SARTM,TVEL,
     *SVEL,DEFWTS(2)
      INTEGER TENG(2),SENG(2)
      DIMENSION TRNG(2),SRNG(2),TWTS(2),SWTS(2),CSURV(5),DEMC(5)
      DO 10 I=1,2
         TENG(I)=0
```

```
            TWTS(I)=0.
            TRNG(I)=0.
            SRNG(I)=0.
            SENG(I)=0
            SWTS(I)=0.
   10 CONTINUE
      JT=0
      JS=0
      TSUM=0.
      SSUM=0.
      DO 100 I=1,5
         WVRNG=RNG(T-TEW*(I-1))
         IF(WVRNG.LT.75.) IL(I)=1
            IF(WVRNG.LT.75.) IWSTAT(I)=1
C
C *** IF THE FIRING RANGE TO A WAVE IS LESS THAN 75 METERS,
C     THE WAVE IS CONSIDERED TO HAVE REACHED A COVERED AND
C     CONCEALED POSITION ON THE BEACH
C
               IF((WVRNG.GT.TENGMX).OR.(CSURV(I).LT.0.05).OR.
     *(WVRNG.LT.75.).OR.(JT.GE.2)) GO TO 50
                  JT=JT+1
                  TENG(JT)=I
                  TWTS(JT)=DEFWTS(JT)*CSURV(I)
                  TSUM=TSUM+TWTS(JT)
                  TRNG(JT)=WVRNG
   50          IF((WVRNG.GT.SENGMX).OR.(CSURV(I).LT.0.05).OR.
     *(WVRNG.LT.SENGMN).OR.(JS.GE.2)) GO TO 100
                  JS=JS+1
                  SENG(JS)=I
                  SRNG(JS)=WVRNG
                  SWTS(JS)=DEFWTS(JS)*CSURV(I)
                  SSUM=SSUM+SWTS(JS)
  100 CONTINUE
C
C *** DETERMINE WAVE STATUS
C
      DO 20 I=1,2
         DO 25 J=1,5
            IF(IWSTAT(J).NE.1.AND.SENG(I).EQ.J) IWSTAT(J)=2
   25    CONTINUE
   20 CONTINUE
      DO 30 I=1,2
         DO 35 J=1,5
            IF(IWSTAT(J).EQ.1) GO TO 35
               IF(IWSTAT(J).EQ.2.AND.TENG(I).EQ.J) IWSTAT(J)=4
                  IF(IWSTAT(J).NE.2.AND.TENG(I).EQ.J) IWSTAT(J)=3
   35    CONTINUE
   30 CONTINUE
C
      IF(TENG(1).EQ.0) GO TO 500
         DO 200 I=1,2
            TWTS(I)=TWTS(I)/TSUM
  200    CONTINUE
  500 IF(SENG(1).EQ.0) RETURN
         DO 600 I=1,2
            SWTS(I)=SWTS(I)/SSUM
  600    CONTINUE
      RETURN
      END
C
C
C
      SUBROUTINE DATAIN
C *** SUBROUTINE DATAIN READS ALL USER SUPPLIED INFORMATION
C     REQUIRED BY THE SHIP-TO-SHORE PHASE OF THE MODEL
C
      COMMON /AMPH/IL(5),WB(2),A(2),B(2),ITE,ISE,RD,WVINT(5),WID,
     *TEW,DINIT(2),GAINL,IWSTAT(5)
      COMMON /ENGR/ SPDMAX,SPDMIN,HTMAX,HTMIN,TTS,TAA,TB,TFF
      COMMON /DISPER/TSIGV(6,2),TSIGH(6,2),TMEANH(6,2),
     *SSIGV(7,2),SSIGH(7,2)
```

```
      COMMON /DEF/TENGMX,SENGMX,SENGMN,TARTM,SARTM,TVEL,
     *SVEL,DEFWTS(2)
      COMMON /SUPEFT/GAMMA,DELTA
      COMMON /IOUT/TSUFV,IPRINT
      READ(5,500) IPRINT
      READ(5,510) SPDMAX,SPDMIN,HTMAX,HTMIN,WID
      READ(5,510) TTS
      READ(5,520) TENGMX,SENGMX,SENGMN
      READ(5,510) TARTM,SARTM,TVEL,SVEL
      READ(5,530) ((TSIGV(I,J),I=1,6),J=1,2)
      READ(5,530) ((TSIGH(I,J),I=1,6),J=1,2)
      READ(5,530) ((TMEANH(I,J),I=1,6),J=1,2)
      READ(5,530) ((SSIGV(I,J),I=1,7),J=1,2)
      READ(5,530) ((SSIGH(I,J),I=1,7),J=1,2)
      READ(5,540) (DEFWTS(I),I=1,2)
      READ(5,550) (WVINT(I),I=1,5)
      READ(5,540) (DINIT(I),I=1,2)
      READ(5,560) (A(I),I=1,2)
      READ(5,560) (B(I),I=1,2)
      READ(5,560) (WB(I),I=1,2)
      READ(5,570) GAINL
      READ(5,570) GAMMA,DELTA
  500 FORMAT(19X,I1)
  510 FORMAT(16X,F6.2,9X,F4.1,8X,F5.1,7X,F5.1,7X,F6.3)
  520 FORMAT(16X,F8.1,16X,F8.1,16X,F8.1)
  530 FORMAT(7X,7F10.3)
  540 FORMAT(35X,F8.1,14X,F8.1)
  550 FORMAT(27X,5F10.5)
  560 FORMAT(46X,F9.5,10X,F9.5)
  570 FORMAT(17X,F7.2,12X,F7.1)
      RETURN
      END
C
C
C
      SUBROUTINE OUTPUT
C *** SUBROUTINE OUTPUT PROVIDES AN INPUT SUMMARY PRINTOUT BASED UPON
C     THE DATA RECEIVED BY SUBROUTINE DATAIN.  A PRINTOUT OF DISPERSION
C     DATA GENERATED AS A RESULT OF DATA SUPPLIED IS ALSO PROVIDED
C
      COMMON /AMPH/IL(5),WB(2),A(2),B(2),ITE,ISE,RD,WVINT(5),WID,
     *TBW,DINIT(2),GAINL,IWSTAT(5)
      COMMON /DISPER/TSIGV(6,2),TSIGH(6,2),TMEANH(6,2),
     *SSIGV(7,2),SSIGH(7,2)
      COMMON /ENGR/ SPDMAX,SPDMIN,HTMAX,HTMIN,TTS,TAA,TB,TFF
      COMMON /DEF/TENGMX,SENGMX,SENGMN,TARTM,SARTM,TVEL,
     *SVEL,DEFWTS(2)
      COMMON /SUPEFT/GAMMA,DELTA
C
C                 *****  INPUT SUMMARY PRINTOUT   *****
C
      WRITE(6,610)
      WRITE(6,612)
      WRITE(6,613)
      WRITE(6,614) (WVINT(I),I=1,5)
      WRITE(6,611) (DINIT(I),I=1,2)
      WRITE(6,615)
      WRITE(6,616)
      WRITE(6,617) SPDMAX,SPDMIN,HTMAX,HTMIN,WID
      WRITE(6,618)
      WRITE(6,619)
      WRITE(6,620)
      WRITE(6,621) TENGMX,TARTM,TVEL
      WRITE(6,622) SENGMX,SENGMN,SARTM,SVEL
      WRITE(6,623) DEFWTS(1),DEFWTS(2)
      WRITE(6,624)
      WRITE(6,625)
      WRITE(6,626) A(1),B(1)
      WRITE(6,627) A(2),B(2)
      WRITE(6,628)
      WRITE(6,629) WB(1),WB(2)
      WRITE(6,630)
```

```
      WRITE(6,631) GAINL
      WRITE(6,632) GAMMA,DELTA
C
C                *****  DISPERSION DATA PRINTOUT  *****
C
      IDISP=1
      IF (IDISP.EQ.0) RETURN
         WRITE(6,633)
         WRITE(6,634)
      DO 55 I=1,6
         WRITE(6,635) TSIGV(I,1),TSIGV(I,2),TSIGH(I,1),TSIGH(I,2),
     *TMEANH(I,1),TMEANH(I,2)
   55 CONTINUE
      WRITE(6,636)
      DO 56 I=1,7
         WRITE(6,637) SSIGV(I,1),SSIGV(I,2),SSIGH(I,1),SSIGH(I,2)
   56 CONTINUE
      WRITE(6,638)
      WRITE(6,639)
C
  610 FORMAT('1',1X,'** INITIAL SHIP-TO-SHORE PHASE INFORMATION **')
  612 FORMAT(/6X,'INITIAL FORCE STRENGTH')
  613 FORMAT(1X,'WAVE',2X,'1',5X,'2',5X,'3',5X,'4',5X,'5')
  614 FORMAT(1X,'LVA',5(2X,F4.1))
  611 FORMAT(/1X,'DEF. TANK ASSETS =',1X,F4.1,5X,
     *'DEF. ATGM ASSETS =',1X,F4.1)
  615 FORMAT(/11X,'LVA ENGR SPECS')
  616 FORMAT(1X,'SPDMAX',2X,'SPDMIN',3X,'HTMAX',2X,'HTMIN',3X,'WID')
  617 FORMAT(2X,F5.2,3X,F5.2,3X,F5.2,3X,F4.2,2X,F4.2)
  618 FORMAT(/1X,'DEFENSIVE TACTICAL PARAMETERS')
  619 FORMAT(10X,'RANGE',4X,'AIM-RELOAD',3X,'PROJECTILE')
  620 FORMAT(8X,'MAX',3X,'MIN',4X,'TIME',7X,'VELOCITY')
  621 FORMAT(1X,'TANK',1X,F6.1,5X,F5.2,7X,F6.2)
  622 FORMAT(1X,'ATGM',1X,F6.1,1X,F6.1,2X,F5.2,7X,F6.2)
  623 FORMAT(/,1X,'DEFENSIVE TACTICAL ALLOCATION WEIGHTS:',
     */,1X,'WAVE 1 = ',F5.2,1X,'WAVE 2 = ',F5.2)
  624 FORMAT(/1X,'DEFENSIVE FORCE ATTRITION COEFFICIENTS')
  625 FORMAT(9X,'ALPHA*A',10X,'BETA*A')
  626 FORMAT(1X,'DT',6X,F7.5,9X,F7.5)
  627 FORMAT(1X,'DS',6X,F7.5,9X,F7.5)
  628 FORMAT(/,' AIMED FIRE ATTRITION RATE COEFFICIENTS FOR',
     */,'             DEFENSIVE TANK AND ATGM ASSETS')
  629 FORMAT(/1X,'WBETA(1)=',F7.5,1X,'WBETA(2)=',F7.5)
  630 FORMAT(/1X,'BREAKPOINT ASSUMPTION: 0.3*(TOTAL DEF FORCE)')
  631 FORMAT(/,1X,'DEFENDER ATTRITION LEVEL ALLOWING FOR LAND COMBAT',
     */,1X,F5.2,'*(TOTAL DEFENDER FORCE)')
  632 FORMAT(/1X,'ARTY SUP FACTOR=',F5.1,2X,'ERROR SUP FACTOR=',F5.1)
  633 FORMAT(/1X,'DISPERSION DATA'/)
  634 FORMAT(3X,'RANGE',2X,'TSIGV',2X,'RANGE',2X,'TSIGH',
     *2X,'RANGE',2X,'TMEANH')
  635 FORMAT(1X,F7.1,2X,F5.1,1X,F7.1,1X,F5.1,1X,F7.1,1X,F5.1)
  636 FORMAT(/3X,'RANGE',2X,'SSIGV',2X,'RANGE',2X,'SSIGH')
  637 FORMAT(1X,F7.1,2X,F5.1,1X,F7.1,1X,F5.1)
  638 FORMAT(/,' CURRENT STATUS OF WAVE I VARIABLE DEFINITIONS',//,
     *' 0 - NOT ENGAGING',/,' 1 - LANDED',/,' 2 - UNDER FIRE BY ATGM',/,
     *' 3 - UNDER FIRE BY TANK',/' 4 - UNDER FIRE BY BOTH ATGM & TANK')
  639 FORMAT('1','***** THE SHIP-TO-SHORE PHASE BEGINS *****'///)
      RETURN
      END
C
      SUBROUTINE PHIT(RANGE,W,H,IWPN,SUPFAC,PRHIT)
C *** GIVEN THE RANGE, WIDTH AND HEIGHT OF A TARGET, AS WELL AS, THE
C     TYPE OF WEAPON BEING USED, SUBROUTINE PHIT COMPUTES THE
C     PROBABILITY OF A HIT
C
      COMMON /AMPH/IL(5),WB(2),A(2),B(2),ITE,ISE,RD,WVINT(5),WID,
     *TBW,DINIT(2),GAINL,IWSTAT(5)
      COMMON /DISPER/TSIGV(6,2),TSIGH(6,2),TMEANH(6,2),
     *SSIGV(7,2),SSIGH(7,2)
      COMMON /SUPEFT/GAMMA,DELTA
C
C *** IWPN CODE:  TANK = 1    ATGM = 2
```

```
C                    ***** VARIABLE DEFINITIONS *****
C      TSIGH - THE STD DEV ERROR IN THE HORIZONTAL FOR TANK
C      TSIGV - THE STD DEV ERROR IN THE VERTICAL FOR TANK
C      TMEANH - THE BIAS ERROR IN THE HORIZONTAL FOR TANK
C      TMEANV - THE BIAS ERROR IN THE VERTICAL FOR TANK
C      SSIGV/SSIGH - SIMILAR INTERPRETATIONS FOR THE ATGM
C
       PI=ARCOS(-1.0)
       IF(RANGE.LT.25.) STOP
          IF(IWPN.EQ.1) GO TO 50
C ***  ATGM FIRING DATA COMPUTATIONS
       WMEANH=0.0
       WMEANV=0.0
       CALL INTRP(SSIGV,RANGE,WSIGV,7)
       CALL INTRP(SSIGV,RANGE,WSIGH,7)
C ***  TANK FIRING DATA COMPUTATIONS
   50  WMEANV=0.0
       CALL INTRP(TMEANH,RANGE,WMEANH,6)
       CALL INTRP(TSIGV,RANGE,WSIGV,6)
       CALL INTRP(TSIGH,RANGE,WSIGH,6)
C ***  CONVERSION TO MILS
  100  Z=ARSIN(H/RANGE)
       WSIGV=WSIGV*(1.+DELTA*SUPFAC)
       WSIGH=WSIGH*(1.+DELTA*SUPFAC)
       TGTH=(Z*6400.0)/(2.0*PI)
       TGTW=(ARSIN(W/RANGE))*(6400.0/(2.0*PI))
C
C ***  INSTITUTE NORMALITY ASSUMPTIONS TO COMPUTE HORIZONTAL
C      AND VERTICAL HIT PROBABILITIES
C
       C=-1.0*SQRT(1./2.)
       HOR1=((TGTW/2.)-WMEANH)/WSIGH
       HOR2=(((-1.0*TGTW)/2.0)-WMEANH)/WSIGH
       PHITX=1.0
       IF(ABS(HOR1).GT.8.) GO TO 60
          PHITX=0.5*(ERFC(C*HOR1)-ERFC(C*HOR2))
   60  VER1=((TGTH/2.)-WMEANV)/WSIGV
       VER2=(((-1.0*TGTH)/2.)-WMEANV)/WSIGV
       PHITY=1.0
       IF(ABS(VER1).GT.8.) GO TO 70
          PHITY=0.5*(ERFC(C*VER1)-ERFC(C*VER2))
   70  PRHIT=PHITX*PHITY
       RETURN
       END
C
C
C
       SUBROUTINE INTRP(X,ARG,VAL,N)
C ***  SUBROUTINE INTRP IS A CHECK SUBROUTINE TO INSURE THAT RANGE OF
C      TARGET AND DISPERSION DATA ARE COMPATABLE FOR PROBABILITY OF
C      HIT COMPUTATION IN SUBROUTINE PHIT
C
       DIMENSION X(N,2)
C      WRITE(6,600) ARG
       IF(ARG.LT.X(1,1)) GO TO 30
          DO 10 I=1,N
             IF(ARG.GT.X(I+1,1)) GO TO 10
             DIFF=X(I+1,1)-X(I,1)
             DELTA=ARG-X(I,1)
             VAL=X(I,2)+(DELTA/DIFF)*(X(I+1,2)-X(I,2))
             RETURN
   10     CONTINUE
       IF(ARG.GT.X(N,1)) GO TO 20
          VAL=X(N,2)
          RETURN
   20  WRITE(6,610)
       STOP
   30  WRITE(6,620)
C 600  FORMAT(1X,'ARG*****=',F10.3)
  610  FORMAT(' ERROR IN INTRP ARG.GT.X(N,2)')
  620  FORMAT(' ERROR IN INTRP ARG.LT.X(1,1)')
```

```
      STOP
      END
C
C
C
      SUBROUTINE RATE(RANGE,SPEED,IWPN,SUPFAC,ROF)
C *** GIVEN THE RANGE AND SPEED OF A TARGET ALONG WITH THE TYPE OF
C     WEAPON BEING USED TO FIRE UPON THE TARGET AND THE SUPPRESSION
C     FACTOR THE FIRER IS BEING SUBJECTED TO, SUBROUTINE RATE COMPUTES
C     THE RATE OF FIRE USED AGAINST A PARTICULAR TARGET.
C
      COMMON /CEF/TENGMX,SENGMX,SENGMN,TARTM,SARTM,TVEL,SVEL
      COMMON /SUPEFT/GAMMA,DELTA
      ROF=0.0
      IF(RANGE.LT.25.) RETURN
         IF(IWPN.EQ.2) GO TO 10
            IF(RANGE.GT.TENGMX) RETURN
               TRTM=TARTM*(1.0+GAMMA*SUPFAC)
               DT=TRTM+RANGE/(TVEL+SPEED)
               ROF=1.0/DT
               RETURN
   10    IF(RANGE.GT.SENGMX) RETURN
            IF(RANGE.LT.SENGMN) RETURN
               SRTM=SARTM*(1.0+GAMMA*SUPFAC)
               DT=SRTM+RANGE/(SVEL+SPEED)
               ROF=1.0/DT
      RETURN
      END
C
C
C
C *** IN THE FUNCTIONS HT,SPD, AND RNG, THE ARGUMENT T
C     IS THE TIME SINCE THE WAVE BEING ADDRESSED
C     CROSSED THE 5000 METER OFFSHORE MARK
C
      FUNCTION SPD(T)
      COMMON /ENGR/ SPDMAX,SPDMIN,HTMAX,HTMIN,TTS,TAA,TB,TFF
      IF(T.GT.TAA) GO TO 50
         SPD=SPDMAX
         RETURN
   50 IF(T.GT.TB) GO TO 100
         SPD=SPDMIN+((TB-T)/TTS)*(SPDMAX-SPDMIN)
         RETURN
  100 SPD=SPDMIN
      RETURN
      END
C
      FUNCTION HT(T)
      COMMON /ENGR/ SPDMAX,SPDMIN,HTMAX,HTMIN,TTS,TAA,TB,TFF
      IF(T.GT.TAA) GO TO 50
         HT=HTMAX
         RETURN
   50 IF(T.GT.TB) GO TO 100
         HT=HTMIN+((TB-T)/TTS)*(HTMAX-HTMIN)
         RETURN
  100 HT=HTMIN
      RETURN
      END
C
      FUNCTION RNG(T)
      COMMON /AMPH/IL(5),WB(2),A(2),B(2),ITE,ISE,RD,WVINT(5),WID,
     *TBW,OINIT(2),GAINL,IWSTAT(5)
      COMMON /ENGR/ SPDMAX,SPDMIN,HTMAX,HTMIN,TTS,TAA,TB,TFF
      IF(T.GT.TAA) GO TO 50
         RNG=5000.0-(SPDMAX*T)
         RETURN
   50 IF(T.GT.TB) GO TO 100
         RNG=RD-0.5*(T-TAA)*(SPDMAX+SPD(T))
         RETURN
  100 RNG=RD-(((TB-TAA)/2.0)*(SPDMIN+SPDMAX))-((T-TB)*SPDMIN)
      IF(RNG.LT.75.) RNG=0.0
      RETURN
```

```
      END
C
C
C
C
      SUBROUTINE GROUND(GATM,TSURV,IPRINT,TTS)
C *** THIS IS THE PRIMARY SUBROUTINE OF THE LAND COMBAT PHASE OF
C     THE AMPHIBIOUS OPERATION.  INFORMATION REQUIRED FOR THE OPERATION
C     OF THE LAND COMBAT PHASE IS READ IN AND PRINTED IN A SUMMARY
C     TABLE FOR USER REVIEW.  THE INFORMATION PROVIDED BY ALL OTHER
C     SUBROUTINES USED IN THE LAND COMBAT PHASE ARE USED IN THIS
C     SUBROUTINE AS INPUT TO THE BASIC LAND COMBAT ALGORITHYM
C
      REAL*8 DSEED
      REAL TSURV,TTS,R(3)
      COMMON /GRP1/ IPRDIR(6),ISECND(6),MVTDIR(6),X(6),Y(6),SPD(6)
      COMMON /GRP2/ TA(2),TI(2),TH(2),TM(2),TF1(2),TF2(2),TF3(2),
     *P(2,6),PHH(2,6),PHM(2,6),PKH(2,6),TE(2)
      COMMON /GRP3/ NBU,NRU,FL(6),FC(6),NOI(3),XIC(3,200),YIC(3,200),
     *IDIR(3,200),AVSF,ISPD
     *,IUSTAT(6),II(6),LOST(6,6),VISFRA,VISFRB,SIZETK,
     *SIZETW,NT(6),NF(6),SRF,DISMAX,
     *NLOSC(6,6),VISFR(6,6),RMINTK,RMXTK,RMINTW,RMXTW,OP,TOWFR,LVAFR,
     *PTT(3,3),RF,PCA(6,6),APDA(6,6),LOA(6,6),NA(6),DFL(6),POL(6)
      COMMON /GRP4/ TPOL(6),CLDC(6,6),Q(6,6)
      COMMON /GRP5/ LOT(6,6),RCT(6,6)
      COMMON /HILLS/ XC(100),YC(100),PEAK(100),SX(100),SY(100),RHO(100)
      COMMON /HILLS/ SCALE(100),TWOFFO(100),TWOSCL(100),BASE
      COMMON /HILLS/ NHILLS
      COMMON /COVER/ CXC(150),CYC(150),CPEAK(150),CPXX(150),CPYY(150)
      COMMON /COVER/ CPXY(150),NCVELS
      COMMON /COUNTR/ KH,KHH,KV,KN,KGRS,KELL,KINT
      COMMON /GRID/ LST(10,10),NHL(10,10),LISTH(450),KHREP(100),KTREP
      COMMON /GRID/ LSTC(10,10),NC(10,10),LISTC(400),KCREP(150)
      COMMON /GRP6/ ALPHA(6)
      COMMON /GRP7/ XA(6),YA(6),IMOVE(6)
C***  INITIALIZATION.
C        *** VARIABLE DEFINITIONS *****
C     BL - INITIAL DEFENSIVE FORCE LEVEL
C     RL - INITIAL AGGRESSOR FORCE LEVEL
C     ZL - ZERO LEVEL
      BL=0.0
      RL=0.0
      KP=0
      PAI=3.14159
      ZL=.00001
C
C***  READ TERRAIN DATA FOR LINE OF SIGHT
C***  CHECK FOR STOCHASTIC OR DETERMINISTIC ATTRITION
C           ITRIT-ATTRITION MODE 1=DETERMINISTIC
C                                0=STOCHASITIC
C           DSEED-DOUBLE PRECISION SEED NUMBER
C           PP AND QQ ARE THE BETA DISTRIBUTION PARAMETERS FOR DEF UNITS
C           PD AND QD ARE THE BETA DISTRIBUTION PARAMETERS FOR ATK UNITS
C
      READ(9,500) ITRIT,DSEED
      READ(9,501) PP,QQ
      DO 5 I=1,3
        CALL GGBTR (DSEED,PP,QQ,1,R)
        ALPHA(I)=R(1)
    5 CONTINUE
C
      READ(9,500) ITRIT,DSEED
      READ(9,501) PD,QD
      DO 6 I=4,6
        CALL GGBTR (DSEED,PD,QD,1,R)
        ALPHA(I)=R(1)
    6 CONTINUE
C***  READ IN NUMBER OF ATTACK AND DEFENSE UNITS
C           NBU - NUMBER OF DEFENSIVE UNITS
C           NRU - NUMBER OF AGGRESSOR UNITS
C
```

```
      READ(9,502) NBU,NRU
C
C***  INITIALIZE WEAPON SIZES
C           SIZETK - SIZE OF LVA WEAPON SYSTEM
C           SIZETW - SIZE OF TOW WEAPON SYSTEM
C
      SIZETK=2.5
      SIZETW=2.5
C
C***  READ IN EFFECTIVE WEAPON RANGES
C***  RMINTK AND RMXTK ARE MAX AND MIN RANGES OF LVA MOUNTED WEAPON
C***  RMINTW AND RMXTW FOR MAX AND MIN RANGES OF TOW DEFENSIVE WEAPON
C
      READ(9,503) RMINTK,RMXTK,RMINTW,RMXTW
C
C***  INITIALIZE PM,RF,TOWFR,LVAFR AND NOD
C        PM - PROPORTION OF TIME A MOVING UNIT IS SEARCHING FOR TARGETS
C        RF - DETECTION RATE REDUCTION FACTOR FOR A FIRING UNIT
C             (IN COMPARISON TO A NONFIRING UNIT)
C        TOWFR - FIRING RATE DEFENDING TOW WEAPON SYSTEM
C        LVAFR - FIRING RATE ATTACKING LVA WEAPON SYSTEM
C        NOD - NUMBER OF TIME INTERVALS UNIT I DELAYED IN MOVEMENT
C              (TOO FAR IN FRONT OF OTHER UNITS)
C
      PM=.352
      RF=.5
      TOWFR=.03
      LVAFR=.1
      NOD=2
      DO 10 I=1,NRU
         NOI(I)=125
   10 CONTINUE
      K=NRU+1
      L=NRU+NEL
      DO 15 I=1,L
         II(I)=0
   15 CONTINUE
C
C*** READ IN FORCE LEVELS OF EACH AGGRESSOR UNIT
C
      ISURV= INT(TSURV/NRU)
      DO 20 I=1,NRU
         FL(I)=FLOAT(ISURV)
   20 CONTINUE
C
C*** CHECK FOR TYPE OF ROUTE DETERMINITION
C
      READ(9,504) IRTE,ISPD
C     ***** VARIABLE DEFINITIONS *****
C   IRTE - DENOTES WHETHER USER WANTS TO INPUT ROUTES OR NOT.
C          0 - PROGRAM DETERMINED ROUTES
C          1 - USER DETERMINED ROUTES
C   ISPD - INPUT VARIABLE TO DENOTE USER'S DESIRED SPEED FOR
C          1 -  9 MPH
C          2 - 12 MPH
C          3 - 15 MPH
C          4 - 18 MPH
C          AGGRESSOR FORCE MOVEMENTS
C   AVSC - AVERAGE SPEED OF AGGRESSOR FORCE MOVEMENTS
C   DST  - DISTANCE IN METERS TO BE MOVED EACH TIME STEP BY
C          AN AGGRESSOR UNIT
C
      IF(ISPD.EQ.1) AVSP=9.0
      IF(ISPD.EQ.1) DST=40.232
      IF(ISPD.EQ.2) AVSP=12.0
      IF(ISPD.EQ.2) DST=53.643
      IF(ISPD.EQ.3) AVSP=15.0
      IF(ISPD.EQ.3) DST=67.053
      IF(ISPD.EQ.4) AVSP=18.0
      IF(ISPD.EQ.4) DST=80.463
C
C*** READ IN INITIAL AGGRESSOR UNIT'S LOCATIONS
```

```
C
      CO 25 I=1,NRU
         READ(5,506) XIC(I,1),YIC(I,1)
   25 CONTINUE
      IF(IRTE.EQ.1) GO TC 250
         DO 30 I=1,NRU
            DC 30 J=2,125
               YIC(I,J)=YIC(I,J-1)+CST*(J-1)
               XIC(I,J)=XIC(I,J-1)+CST*(J-1)
               IDIR(I,J)=0
   30       CONTINUE
         GO TO 255
  250 CALL ROUTE
  255 SUMRO=0.C
C        ***** STATE VARIABLE DEFINITICNS *****
C     FL(I) - FCRCE LEVEL CF UNIT I
C     SUMRC - TOTAL AGGRESSOR FCRCE LEVEL
C     MVTDIR(I) - MOVEMENT DIRECTICN CF UNIT I
C     IDIR(I,J) - DIRECTICN CF THE JTH INTERVAL IN THE ITH ROUTE
C     IUSTAT(I) - CURRENT STATUS OF UNIT I
C                 0 - UNIT ALIVE AND NOT FIRING
C                 1 - UNIT ALIVE ANC FIRING
C                 2 - UNIT DESTROYED
C                 3 - UNIT MCVING
C     NF(I) - NUMBER CF TIME INTERVALS UNIT I IS ALLOWED TC FIRE
C             AT SAME LOCATICN
C     II(I) - INTERVAL INDEX FOR UNIT I
C
      DC 35 I=1,NRU
         FO(I)=FL(I)
         SUMRC=SUMRC+FO(I)
         X(I)=XIC(I,1)
         Y(I)=YIC(I,1)
         MVTDIR(I)=ICIR(I,1)
         SPD(I)=AVSP
         IUSTAT(I)=0
         IPRDIR(I)=ICIR(I,1)
         ISECWD(I)=120
         NF(I)=1
         II(I)=1
   35 CCNTINUE
C
C*** READ IN CEFENSIVE UNIT'S LCCATICNS
C              ***** STATE VARIABLE CEFINITICNS *****
C        IPRDIR(I) - PRINCIPLE CIRECTION OF FIRE FOR UNIT I
C        ISECWD(I) - WIDTH OF SEARCH SECTOR FCR UNIT I
C        SUMBC - TCTAL DEFENSIVE FCRCE LEVEL
C
      SUMBC=0.0
      CC 40 I=K,L
         READ(5,507) X(I),Y(I),FL(I),IPRDIR(I),ISECWD(I)
         FO(I)=FL(I)
         SUMBC=SUMBC+FO(I)
         MVTDIR(I)=C
         SPD(I)=0.0
         IUSTAT(I)=0
         IMOVE(I)=C
   40 CCNTINUE
C
C*** CHECK FOR ALTERNATE DEFENSIVE POSITIONS AND READ IN IF WANTED
C           ***** STATE VARIABLE DEFINITIONS *****
C     IALT - INDICATES IF ALTERNATE DEFENSIVE POSITICNS DESIRED
C            0 - YES
C            1 - NO
C     BREAK - CLOSEST DISTANCE ALLOWED BETWEEN OPPOSING FORCES
C             BEFORE BREAKPOINT REACHED FOR PROGRAM
C     ITEM - NUMBER CF TIME INTERVALS ALLOWED FOR DEFENDER'S MOVE
C            TO THE ALTERNATE DEFENSIVE POSITICNS
C     TA(K) - TIME TO ACQUIRE A TGT FOR KTH WEAPON SYSTEM TYPE (K = 1,2)
C     T1(K) - TIME TO FIRE 1ST ROUND AFTER TGT ACQUIRED BY KTH WEAP SYS
C     TH(K) - TIME TO FIRE A ROUND FOLLOWING A HIT FOR KTH WEAP SYS
C     TM(K) - TIME TO FIRE A ROUND FOLLOWING A MISS FOR KTH WEAP SYS
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C      TF1(K) - TIME OF FLIGHT FOR KTH WEAP SYS PROJECTILE TO 1000 METERS
C      TF2(K) - TIME OF FLIGHT FOR KTH WEAP SYS PROJECTILE TO 2000 METERS
C      TF3(K) - TIME OF FLIGHT FOR KTH WEAP SYS PROJECTILE TO 3000 METERS
C
       READ(9,508) IALT,BREAK,ITEM
       IF(IALT.EQ.1) GO TO 260
          DO 45 I=K,L
             READ(9,506) XA(I),YA(I)
   45     CONTINUE
  260  DELT=10.
       TA(1)=20.
       TI(1)=8.
       TH(1)=8.
       TM(1)=10.
       TF1(1)=1.
       TF2(1)=1.
       TF3(1)=1.
       TA(2)=20.
       TI(2)=8.
       TH(2)=8.
       TM(2)=15.
       TF1(2)=10.
       TF2(2)=12.
       TF3(2)=15.
C
C*** READ IN HIT AND KILL PROBABILITIES
C             ***** STATE VARIABLE DEFINITIONS *****
C      P(I,J) - PROB 1ST ROUND HIT BY UNIT I IN RANGE BAND J
C      PHH(I,J) - PROB OF HIT FOLLOWED BY A HIT
C      PHM(I,J) - PROB OF HIT FOLLOWED BY A MISS
C      PKH(I,J) - PROB OF A KILL GIVEN A HIT
C      PTT(I,J) - PROPORTION SURVIVING FIRE POWER ALLOCATED TO
C                 ITH TARGET IF J TARGETS ARE AVAILABLE
C      NLOSC(I,J) - NUMBER OF CONTINUOUS TIME INTERVALS THAT A LINE OF
C                   SIGHT(LOS) DOES NOT EXIST BETWEEN UNIT I AND UNIT J
C      Q(I,J) - PROBABILITY UNIT J NOT DETECTED BY UNIT I AT CURRENT TIME
C      VISFR(I,J) - FRACTION OF HEIGHT OF TGT J VISIBILE TO FIRER I
C      IRAN - RANGE
C
       DO 55 I=1,2
          DO 50 J=1,6
             READ(9,509) P(I,J),PHH(I,J),PHM(I,J),PKH(I,J)
   50     CONTINUE
   55  CONTINUE
       PTT(1,1)=1.0
       PTT(1,2)=0.8
       PTT(2,2)=0.2
       PTT(1,3)=0.8
       PTT(2,3)=0.15
       PTT(3,3)=0.05
       DO 60 I=1,NRU
          DO 60 J=K,L
             NLOSC(I,J)=0
             NLOSC(J,I)=0
             Q(I,J)=1.0
             Q(J,I)=1.0
             VISFR(I,J)=0.0
             VISFR(J,I)=0.0
   60  CONTINUE
       IC=1
C
C*** PRINT INITIAL BATTLE INFORMATION
C
       WRITE(6,600)
       WRITE(6,601)
       DO 65 I=1,L
          WRITE(6,603) I,X(I),Y(I),FL(I)
   65  CONTINUE
       IF(ITRIT.EQ.1) GO TO 265
          WRITE(6,604)
          GO TO 270
  265  WRITE(6,605)
```

```
  270 IF(IRTE.EQ.0) GO TO 275
          WRITE(6,606)
  275 WRITE(6,607) AVSF
      WRITE(6,608) BREAK
      IF(IALT.EQ.0) GO TO 280
          WRITE(6,609)
          GO TO 285
  280 WRITE(6,610)
      DO 70 I=K,L
          WRITE(6,611) I,XA(I),YA(I)
   70 CONTINUE
  285 IRAN=500
      WRITE(6,612)
      DO 75 I=1,6
          WRITE(6,613) IRAN,P(1,I),PHH(1,I),PHM(1,I),PKH(1,I)
          IRAN=IRAN+500
   75 CONTINUE
      IRAN=500
      WRITE(6,614)
      DO 80 I=1,6
          WRITE(6,613) IRAN,P(2,I),PHH(2,I),PHM(2,I),PKH(2,I)
          IRAN=IRAN+500
   80 CONTINUE
      WRITE(6,615)
      WRITE(6,617)
      WRITE(6,618)
C*** UPDATE LOCATION OF RED UNITS.
C         NF - NUMBER OF TIME INTERVALS UNIT I DOES NOT FIRE
C         NOD - NUMBER OF TIME INTERVALS UNIT I DELAYED IN MOVEMENT
C
      DISMAX=5000.0
  290 DO 90 I=1,NRU
          IF( IUSTAT(I).EQ.2) GO TO 90
              IF(IUSTAT(I).EQ.0) GO TO 295
                  NF(I)=NF(I)+1
                      IF(NF(I).LT.NOD) GO TO 90
                          NF(I)=1
  295     DO 85 J = 1, NRU
              IF (J .EQ. I) GO TO 85
                  IF (IUSTAT(J) .EQ. 2) GO TO 85
                      DIST = X(I) - X(J)
                          IF (DIST .GT. DISMAX) GO TO 90
   85     CONTINUE
          II(I) = II(I) + 1
          K7=II(I)
          X(I)=XIC(I,K7)
          Y(I)=YIC(I,K7)
          MVTDIF(I)=IDIR(I,K7)
          IPRDIF(I)=IDIF(I,K7)
   90 CONTINUE
C
C     LINE--OF-SIGHT CHECK BETWEEN UNITS AND TARGETS SELECTION
C           ***** STATE VARIABLE DEFINITIONS *****
C     NT(I) - NUMBER OF TARGETS DETECTED BY UNIT I
C     XX1,YY1 - COORDINATES OF UNIT I LOCATION
C     XX2,YY2 - COORDINATES OF UNIT J LOCATION
C     TMACI,TMACJ - ELEVATION OF UNIT I AND UNIT J
C     0,0 - INDICATES NO UNITS UNDER GROUND
C     SIZETK,SIZETW - SIZE OF LVA VEHICLE AND SIZE OF TOW VEHICLE
C     LATOB - INDICATOR VARIABLE FOR ONE OR TWO WAY LOS CALLS
C                 0 - DO NOT COMPUTE LOS FROM UNIT A TO UNIT B
C                 1 - COMPUTE LOS FROM UNIT A TO UNIT B
C                         (YIELDING VISFRB)
C     VISFRA - FRACTION OF HEIGHT OF TGT AS SEEN BY UNIT A
C     LOST(I,J) - INDICATES IF LOS EXISTS BETWEEN UNIT I AND UNIT J
C                 0 - NO LOS EXISTS      1 - LOS EXISTS
C
      DO 95 J=K,L
          NT(J)=0
   95 CONTINUE
      DO 105 I=1,NRU
          NT(I)=0
```

```
      IF(IUSTAT(I).EC.2) GO TO 105
         DO 100 J=K,L
            IF(IUSTAT(J).EQ.2.OR.IUSTAT(J).EQ.3) GO TO 100
              XX1=X(I)
              YY1=Y(I)
              CALL ELEV(XX1,YY1,TMACI)
              XX2=X(J)
              YY2=Y(J)
              CALL ELEV(XX2,YY2,TMACJ)
              LATOB=1
              LBTOA=1
              CALL LOS(XX1,YY1,TMACI,0.0,SIZETK,XX2,YY2,TMACJ,C.0,
     *SIZETW,LATOB,LBTOA,VISFRA,VISFRB)
              VISFR(I,J)=VISFRA
              VISFR(J,I)=VISFRB
              IF(VISFRA.GT.ZL) GOTO 300
                LOST(I,J)=0
                LOST(J,I)=0
                NLOSC(I,J)=NLOSC(I,J)+1
                NLOSC(J,I)=NLOSC(I,J)
                GO TO 100
300           LOST(I,J)=1
              LOST(J,I)=1
              NLOSC(I,J)=0
              NLOSC(J,I)=0
              RANGE=SQRT((X(I)-X(J))**2+(Y(I)-Y(J))**2)
              IF(RANGE.LT.RMINTK.OR.RANGE.GT.RMXTK) GC TO 305
                IF(Q(I,J).EQ.1.0) GO TO 305
                  IUSTAT(I)=1
                  NT(I)=NT(I)+1
                  M=NT(I)
                  LOT(I,M)=J
                  RCT(I,M)=RANGE
                    IF(M.EQ.1) GO TO 305
                      CALL SORT(I,M)
305           IF(RANGE.LT.RMINTW.OR.RANGE.GT.RMXTW) GO TO 100
                IF(Q(J,I).EC.1.C) GO TO 100
                  IUSTAT(J)=1
                  NT(J)=NT(J)+1
                  M=NT(J)
                  LOT(J,M)=I
                  ROT(J,M)=RANGE
                  IF(M.EC.1) GO TO 100
                    CALL SORT(J,M)
100         CONTINUE
105   CONTINUE
      DO 110 I=1,NRU
        IF(IUSTAT(I).EC.2) GC TO 110
          IF(NT(I).NE.0) GO TO 110
            IUSTAT(I)=0
            NF(I)=0
110   CONTINUE
      DO 115 J=K,L
        IF(IUSTAT(J).EC.2.OR.IUSTAT(J).EQ.3) GC TO 115
          IF(NT(J).EC.0) IUSTAT(J)=0
115   CONTINUE
C
C*** UPDATE OF THE ACCUMULATED DETECTION PROBABILITIES.
C
      IAA=1
      IBB=NRU
      ICC=K
      IDD=L
      FF=TOWFF
      OF=PM
      DO 120 I=1,6
120   CONTINUE
307   DO 135 I=IAA,IBB
        IF(IUSTAT(I).EC.2.OR.IUSTAT(I).EQ.3) GO TO 135
          DO 130 J=ICC,IDD
            PROP=C.C
            IF(IUSTAT(J).EQ.2.OR.IUSTAT(J).EQ.3) GO TO 130
```

```
      CLCQ(I,J)=C(I,J)
      IF(LCST(I,J).EQ.C) GO TO 350
         IF(NT(I).GT.0) GO TO 315
            PCTVIS=VISFR(J,I)
            CALL LAMDA(I,J,PCTVIS,DETRAT,PSUBK)
            QV=EXP(-(DETRAT*OP*DELT*FL(J)))
            IF(NT(J).GT.C) GO TO 310
               Q(I,J)=Q(I,J)*QV
               GO TO 130
310         QP=(1.0-PSUBK)**(FR*DELT*FL(J))
            Q(I,J)=C(I,J)*(QV+QP-QV*QP)
            GO TO 130
315      N5=NT(I)
         DC 125 I1=1,N5
            K1=LOT(I,I1)
            ANG1=ATAN2(Y(K1)-Y(I),X(K1)-X(I))
            ANG2=ATAN2(Y(J)-Y(I),X(J)-X(I))
            IF((ANG1*ANG2).GE.0.0) GO TO 330
               IF(ANG2.LT.0.0) GC TO 320
                  ANG=2*PAI+ANG1-ANG2
                  GO TO 325
320            ANG=2*PAI+ANG2-ANG1
325            IF(ANG.GT.PAI) ANG=2*PAI-ANG
                  GO TO 335
330         ANG=ABS(ANG2-ANG1)
335         AA=15.0*PAI/180.0
            IF(ANG.GT.AA) GC TO 125
               PROP=PROP+PTT(I1,N5)
125      CCNTINUE
         IF(PRCP.EQ.0.C) GO TO 345
            IF(NT(J).GT.0)GOTO 340
               CALL LAMCA(I,J,FCTVIS,DETRAT,PSUBK)
               DETRAT=DETRAT*RF
               QV=EXP(-(PROP*DETRAT*DELT*FL(J)))
               Q(I,J)=C(I,J)*QV
               GO TO 13C
34C        Q(I,J)=0.C
           GO TO 130
345     IF(IAA.EQ.1) GO TC 130
           Q(I,J)=1.C
           GC TO 130
350        IF(NLOSC(I,J).LE.3) GO TO 130
              C(I,J)=1.0
130      CONTINUE
135  CCNTINUE
     IF(IAA.EQ.K) GC TC 355
        FR=LVAFR
        IAA=K
        IBB=L
        ICC=1
        IDD=NFU
        OP=1.C
        GO TO 307
C
C*** FIRE ALLOCATICN.
C              ***** STATE VARIABLE DEFINITIONS *****
C       APCA(I,J) - AVERAGE PROPCRTICN OF THE JTH AGGRESSCR OF UNIT I
C                   ALLCCATED TO FIRE CN UNIT I
C
 355 DO 140 I=1,L
 140    NA(I)=C
           DO 155 I=1,L
              IF(IUSTAT(I).EQ.2.OR.IUSTAT(I).EQ.3) GO TO 155
                 IF(NT(I).EC.0) GO TO 155
                    DO 145 J=1,3
                       APCA(I,J)=C.C
 145                CONTINUE
                    IF(NT(I).EQ.1) GO TO 370
                       IF(NT(I).EQ.2) GO TC 365
                          NOT=3
                          MM1=LOT(I,1)
                          MM2=LOT(I,2)
```

```
                    MM3=LOT(I,3)
                    PROB=(1.0-Q(I,MM1))*Q(I,MM2)*Q(I,MM3)
                    APOA(I,1)=APOA(I,1)+PTT(1,1)*PROB
                    PROB=Q(I,MM1)*(1.0-Q(I,MM2))*Q(I,MM3)
                    APOA(I,2)=APOA(I,2)+PTT(1,1)*PROB
                    PROB=Q(I,MM1)*Q(I,MM2)*(1.0-Q(I,MM3))
                    APOA(I,3)=APOA(I,3)+PTT(1,1)*PROB
                    PROB=(1.0-Q(I,MM1))*(1.0-Q(I,MM2))*Q(I,MM3)
                    APOA(I,1)=APOA(I,1)+PTT(1,2)*PROB
                    APOA(I,2)=APOA(I,2)+PTT(2,2)*PROB
                    PROB=(1.0-Q(I,MM1))*Q(I,MM2)*(1.0-Q(I,MM3))
                    APOA(I,1)=APOA(I,1)+PTT(1,2)*PROB
                    APOA(I,3)=APOA(I,3)+PTT(2,2)*PROB
                    PROB=Q(I,MM1)*(1.0-Q(I,MM2))*(1.0-Q(I,MM3))
                    APOA(I,2)=APOA(I,2)+PTT(1,2)*PROB
                    APOA(I,3)=APOA(I,3)+PTT(2,2)*PROB
              PROB=(1.0-Q(I,MM1))*(1.0-Q(I,MM2))*(1.0-Q(I,MM3))
                    APOA(I,1)=APOA(I,1)+PTT(1,3)*PROB
                    APOA(I,2)=APOA(I,2)+PTT(2,3)*PROB
                    APOA(I,3)=APOA(I,3)+PTT(3,3)*PROB
 360                DO 150 J=1,NCT
                    KK=LOT(I,J)
                    NA(KK)=NA(KK)+1
                    IN=NA(KK)
                    LOA(KK,IN)=I
                    POA(KK,IN)=APOA(I,J)
 150                CONTINUE
                    GO TO 155
 365          NCT=2
              MM1=LOT(I,1)
              MM2=LOT(I,2)
              PROB=(1.0-Q(I,MM1))*Q(I,MM2)
              APOA(I,1)=APOA(I,1)+PTT(1,1)*PROB
              PROB=Q(I,MM1)*(1.0-Q(I,MM2))
              APOA(I,2)=APOA(I,2)+PTT(1,1)*PROB
              PROB=(1.0-Q(I,MM1))*(1.0-Q(I,MM2))
              APOA(I,1)=APOA(I,1)+PTT(1,2)*PROB
              APOA(I,2)=APOA(I,2)+PTT(2,2)*PROB
              GO TO 360
 370         NCT=1
             MM1=LOT(I,1)
             PROB=1.0-Q(I,MM1)
             APOA(I,1)=APOA(I,1)+PTT(1,1)*PROB
             GO TO 360
 155 CONTINUE
C
C*** ATTRITION COMPUTATION
C          ***** STATE VARIABLE DEFINITIONS *****
C     RANGE - CURRENT MINIMUM DISTANCE BETWEEN AGGRESSOR AND DEFENDER
C     POA - PROPORTION OF THE JTH ATTACKER OF UNIT I ALLOCATED TO
C           FIRE ON UNIT I
C     TPOL - TOTAL PERCENTAGE LOST SINCE START OF BATTLE FOR UNIT I
C     AVD - AVERAGE DISTANCE
C
      SUMR=0.0
      SUMB=0.0
      DO 165 I=1,L
         IF(IUSTAT(I).EQ.2.OR.IUSTAT(I).EQ.3) GO TO 165
         M6=NA(I)
         SUM=0.0
            IF(M6.EQ.0) GO TO 395
            DO 160 J=1,M6
               M7=LOA(I,J)
               IF(M7.LT.K) GO TO 375
                  ITYPE=2
                  GO TO 380
 375           ITYPE=1
 380           RANGE=SQRT((X(I)-X(M7))**2+(Y(I)-Y(M7))**2)
               IF(ITRIT.EQ.1) GO TO 385
                  CALL STOCH(ITYPE,RANGE,AJI)
                  GO TO 390
 385           CALL ETK(ITYPE,RANGE,T)
```

```
                 AJI=1.0/T
390              SUM=SUM+AJI*FL(M7)*PDA(I,J)*DELT
160           CONTINUE
395       OFL(I)=FL(I)
          FL(I)=FL(I)-SUM
          IF(FL(I).GT.ZL) GO TO 400
            FL(I)=0.0
            IUSTAT(I)=2
400       IF(I.LT.K) GO TO 405
            SUMB=SUMB+FL(I)
            TPOL(I)=(FO(I)-FL(I))/FO(I)
            GO TO 165
405       SUMR=SUMR+FL(I)
          TPOL(I)=(FO(I)-FL(I))/FO(I)
  165 CONTINUE
C
C*** PRINT AND CHECK FOR BATTLE TERMINATION.
C
C
      IITIME=IC*INT(TTS)
      DO 175 I=K,L
        IF(IUSTAT(I).EQ.2) GO TO 175
          DO 170 J=1,NRU
            IF(IUSTAT(J).EQ.2) GO TO 170
              CHECK=X(I)-X(J)
              AVD=SQRT((X(I)-X(J))**2+(Y(I)-Y(J))**2)
              IF(AVD.LT.BREAK.OR.CHECK.LT.50.) GO TO 410
170       CONTINUE
175 CONTINUE
      GO TO 415
C
C*** COMPLETE AGGRESSOR UNIT'S MOVE
C
  410 DO 180 I=K,L
        IF(I.LT.EC.1.OR.IMOVE(I).EQ.ITEM) GO TO 440
          IF(IUSTAT(I).EQ.0) IUSTAT(I)=3
            IMOVE(I)=IMOVE(I)+1
            IF(IMOVE(I).LT.ITEM) GO TO 180
              X(I)=XA(I)
              Y(I)=YA(I)
              IF(IUSTAT(I).EQ.3) IUSTAT(I)=0
180         CONTINUE
415         IITIME=ITIME+IFIX(GATM)
            IF(IPRINT.EQ.1) GO TO 430
              WRITE(6,622) IITIME
              WRITE(6,623)
              WRITE(6,624)
              DO 185 I=1,NRU
                N6=NT(I)
                IF(N6.NE.0) GO TO 420
                  WRITE(6,625) I,X(I),Y(I),FL(I),IUSTAT(I),TPOL(I)
                  GO TO 185
420               WRITE(6,626)I,X(I),Y(I),FL(I),IUSTAT(I),TPOL(I),
     *(LOT(I,J),J=1,N6)
185           CONTINUE
              WRITE(6,627)
              WRITE(6,628)
              NNN=NRU+1
              DO 190 I=NNN,L
                N6=NT(I)
                IF(N6.NE.0) GO TO 425
                  WRITE(6,629) I,X(I),Y(I),FL(I),IUSTAT(I),TPOL(I)
                  GO TO 190
425               WRITE(6,630)I,X(I),Y(I),FL(I),IUSTAT(I),TPOL(I),
     *(LOT(I,J),J=1,N6)
190           CONTINUE
  430 CONTINUE
C
C*** CHECK FOR BATTLE TERMINATION.
C
      ICT=0
C*** CHECK IF AN AGGRESSOR FORCE UNIT IS STILL ALIVE
```

```
      DO 195 I=1,NRU
         IF(FL(I).EQ.0.0) GO TO 195
         IOT=1
  195 CONTINUE
       IF(IOT.EQ.1) GO TO 435
C*** NO AGGRESSOR FORCE UNIT ALIVE SO DEFENDER WINS
         WRITE(6,631)
         GO TO 450
  435 IOT=0
C*** CHECK IF A DEFENSIVE FORCE UNIT IS STILL ALIVE
      DO 200 I=K,L
         IF(FL(I).EQ.0.0) GO TO 200
         IOT=1
  200 CONTINUE
       IF(IOT.EQ.1) GO TO 445
C*** NO DEFENSIVE FORCE UNIT ALIVE SO AGGRESSOR WINS
         WRITE(6,632)
         GO TO 450
C*** DISTANCE BETWEEN FORCES TOO CLOSE
  440    WRITE (6,633)
         GO TO 450
  445 IC=IC+1
      GO TO 290
  450 CONTINUE
      WRITE(6,622) IITIME
      WRITE(6,623)
      WRITE(6,624)
      DO 205 I=1,NRU
         N6=NT(I)
         IF(N6.NE.0) GO TO 455
            WRITE(6,625) I,X(I),Y(I),FL(I),IUSTAT(I),TPOL(I)
            GO TO 205
  455    WRITE(6,626)I,X(I),Y(I),FL(I),IUSTAT(I),TPOL(I),
     *(LOT(I,J),J=1,N6)
  205 CONTINUE
      WRITE(6,627)
      WRITE(6,628)
      NNN=NRU+1
      DO 210 I=NNN,L
         N6=NT(I)
         IF(N6.NE.0) GO TO 460
            WRITE(6,629) I,X(I),Y(I),FL(I),IUSTAT(I),TPOL(I)
            GO TO 210
  460    WRITE(6,630)I,X(I),Y(I),FL(I),IUSTAT(I),TPOL(I),
     *(LOT(I,J),J=1,N6)
  210 CONTINUE
  500 FORMAT(18X,I2,12X,F10.2)
  501 FORMAT(35X,F12.2,7X,F12.2)
  502 FORMAT(18X,I2,18X,I2)
  503 FORMAT(10X,F7.1,10X,F7.1,10X,F7.1,10X,F7.1)
  504 FORMAT(18X,I2,18X,I2)
  506 FORMAT(12X,F8.1,12X,F8.1)
  507 FORMAT(12X,F8.1,12X,F8.1,6X,F4.1,7X,I3,7X,I3)
  508 FORMAT(19X,I1,12X,F8.1,13X,I1)
  509 FORMAT(5X,F5.2,5X,F5.2,5X,F5.2,5X,F5.2)
  600 FORMAT('1',1X,'** INITIAL LAND COMBAT INFORMATION **',
     *////,'                  LOCATION')
  601 FORMAT(' ','UNIT',7X,'X',8X,'Y',4X,'FORCE LEVEL')
  603 FORMAT(1X,I3,3X,F7.1,2X,F7.1,7X,F5.1)
  604 FORMAT(/1X,'ATTRITION IS STOCHASTIC'/)
  605 FORMAT(/1X,'ATTRITION IS DETERMINISTIC'/)
  606 FORMAT(1X,'ROUTES DETERMINED BY USER'/)
  607 FORMAT(1X,'ATTACK VEHICLE SPEED IS ',F4.1,' M.P.H.',/)
  608 FORMAT(1X,'BREAKPOINT DISTANCE IS ',F6.1,' METERS',/)
  609 FORMAT(1X,'DEFENDER WILL NOT MOVE TO ALTERNATE POSITIONS'/)
  610 FORMAT(1X,'DEFENDER WILL MOVE TO ALTERNATE POSITIONS'/1X,
     *'ALTERNATE POSITIONS ARE:'/1X,'UNIT',5X,'X',8X,'Y')
  611 FORMAT(1X,I3,3X,F7.1,2X,F7.1)
  612 FORMAT(/4X,'ATK KILL PROBABILITIES'/1X,'RANGE',4X,'P',
     *4X,'PHH',3X,'PHM',3X,'PKH')
  613 FORMAT(2X,I4,4(2X,F4.2))
  614 FORMAT(/4X,'DEF. KILL PROBABILITIES'/1X,'RANGE',4X,'P',
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     *4X,'PHH',3X,'PHM',3X,'PKH')
  615 FORMAT(//,' CURRENT STATUS OF UNIT I VARIABLE DEFINITIONS',//,
     *' 0 - ALIVE NOT FIRING',/,' 1 - ALIVE AND FIRING',/,
     *' 2 - KILLED',/,' 3 - MOVING')
  617 FORMAT(//,' VEHICLE SPEED VARIABLE DEFINITIONS',//,
     *' 1 -  9 MPH',/,' 2 - 12 MPH',/,' 3 - 15 MPH',/,' 4 - 18 MPH')
  618 FORMAT('1',10X,' ***** THE LAND COMBAT PHASE BEGINS *****',//)
  622 FORMAT(//1X,'TIME=',I4,1X,'SECONDS'//)
  623 FORMAT(/,' AGGRESSOR UNIT INFORMATION')
  624 FORMAT(1X,'UNIT',5X,'X',8X,'Y',5X,'FORCE LEVEL',2X,'STATUS',
     *2X,'LOST-PCT',2X,'TARGETS')
  625 FORMAT(3X,I1,3X,F7.1,2X,F7.1,6X,F5.1,9X,I1,6X,F5.3)
  626 FORMAT(3X,I1,3X,F7.1,2X,F7.1,6X,F5.1,9X,I1,6X,F5.3,3X,3(I1,1X))
  627 FORMAT(/,' DEFENSIVE UNIT INFORMATION')
  628 FORMAT(1X,'UNIT',5X,'X',8X,'Y',5X,'FORCE LEVEL',2X,'STATUS',
     *2X,'LOST-PCT',2X,'TARGETS')
  629 FORMAT(3X,I1,3X,F7.1,2X,F7.1,6X,F5.1,9X,I1,6X,F5.3)
  630 FORMAT(3X,I1,3X,F7.1,2X,F7.1,6X,F5.1,9X,I1,6X,F5.3,3X,3(I1,1X))
  631 FORMAT(1X,'***** AGGRESSOR FORCE IS ELIMINATED.  END OF BATTLE.')
  632 FORMAT(1X,' **** DEFENSIVE FORCE IS ELIMINATED. END OF BATTLE.')
  633 FORMAT(1X,'***** DISTANCE BETWEEN FORCES IS TOO CLOSE. ',
     *'END OF BATTLE *****')
      RETURN
      END
C
      SUBROUTINE SETUP
C *** SUBROUTINE SETUP IS USED TO READ IN THE TERRAIN DATA AND
C     CREATE PARAMETRIC TERRAIN. THIS TERRAIN DATA WILL BE USED
C     WHEN COMPUTING LINE-OF-SIGHT BETWEEN TARGETS AND OBSERVERS
C     AS WELL AS PROVIDING A GRID SYSTEM FOR UNIT LOCATIONS AND
C     MOVEMENT.
C
      COMMON /HILLS/ XC(100),YC(100),PEAK(100),ANGH(100),SPRD(100)
      COMMON /HILLS/ ECC(100),PXX(100),PYY(100),PXY(100),BASE
      COMMON /HILLS/ NHILLS
      COMMON /COVER/ CXC(150),CYC(150),CPEAK(150),CPXX(150),CPYY(150)
      COMMON /COVER/ CPXY(150),NCVELS
      COMMON /COUNTR/KH,KHH,KV,KN,KCFS,KELL,KINT
      COMMON /GRID/ LST(5,4),NHL(5,4),LISTH(150),KHREF(150),KTREP
      COMMON /GRID/ LSTC(5,4),NC(5,4),LISTC(400),KCREF(150)
      PAI=3.14159
      READ(5,500) NHILLS
      READ(5,510) BASE
      DO 50 I=1,NHILLS
         READ(5,520) XC(I),YC(I),PEAK(I),ANGH(I),SPRD(I),ECC(I)
   50 CONTINUE
      READ(5,530)LST
      READ(5,530)NHL
      READ(5,500)NHTCT
      READ(5,530)(LISTH(I),I=1,NHTCT)
   65 DO 100 I=1,NHILLS
         AANGLE=ANGH(I)*PAI/180.
         SANG=SIN(AANGLE)
         CANG=COS(AANGLE)
         A=PEAK(I)/(PEAK(I)-50.)
         A=ALOG(A)
         B=A*ECC(I)**2
         SSPD=SPRD(I)**2
         PXX(I)=-(A*CANG*CANG+B*SANG*SANG)/SSPD
         PYY(I)=-(A*SANG*SANG+B*CANG*CANG)/SSPD
         PXY(I)=(2.*SANG*CANG*(B-A))/SSPD
         KHREF(I)=-2147483600
C  ALL VALUES NOW IN METERS ON 0 -- 10,000 GRID
  100 CONTINUE
      READ(5,500) NCVELS
      IF(NCVELS.EQ.0) GO TO 200
         DO 150 I=1,NCVELS
            READ(5,540)CXC(I),CYC(I),CPEAK(I),CPXX(I),CPYY(I),CPXY(I)
            KCREF(I)=-2147483600
  150    CONTINUE
         READ(5,530)LSTC
         READ(5,530)NC
```

```
      READ(5,500)NCTOT
      READ(5,530)(LISTC(I),I=1,NCTOT)
200   KTREP=-2147483600
      KH=0
      KHW=0
      KV=C
      KN=0
      KGFS=0
      KELL=0
      KINT=0
500   FORMAT(36X,I4)
510   FORMAT(16X,F5.1)
520   FORMAT(13X,F7.1,3X,F7.1,5X,F6.1,5X,F6.2,5X,F8.2,4X,F4.1)
530   FORMAT(15X,10I5)
540   FORMAT(3F10.4,3E13.7)
      RETURN
      END
C
      SUBROUTINE ROUTE
C
C *** SUBROUTINE ROUTE COMPUTES THE ROUTE OF EACH AGGRESSOR UNIT
C     WHEN THE USER HAS SELECTED THE OPTION OF INPUTING AGGRESSOR
C     ROUTES. IT CALCULATES THE COORDINATES OF EACH INTERVAL ENDPOINT
C     ALONG THE ROUTE,MAKING EACH INTERVAL LENGTH(DISTANCE MOVED DURING
C     A 10 SECOND TIME STEP) THE SAME. THE INTERVAL LENGTH IS DETERMINED
C     BY THE SPEED THE USER HAS SELECTED AND INPUTED FOR THE CURRENT
C     BATTLE.
C
      COMMON /GFP3/ NEU,NRU,FL(6),FO(6),NOI(3),XIC(3,200),YIC(3,200),
     *IDIR(3,200),AVSP,ISPD
     *,IUSTAT(6),II(6),LCST(6,6),VISFRA,VISFRB,SIZETK,
     *SIZETW,NT(6),NF(6),SRF,DISMAX,
     *NLCSC(6,6),VISFR(6,6),RMINTK,RMXTK,RMINTW,RMXTW,CP,TOWER,LVAFR,
     *PTT(3,3),RF,PCA(6,6),APCA(6,6),LOA(6,6),NA(6),OFL(6),PCL(6)
      DIMENSION XLOC(3,20),YLOC(3,20),N(3)
      IF(ISPD.EQ.4) CST=80.463
      IF(ISPD.EQ.3) CST=67.053
      IF(ISPD.EQ.2) CST=53.643
      IF(ISPD.EQ.1) CST=40.232
      DO 110 I=1,NRU
         READ(5,500) N(I)
         NL=N(I)+1
         DO 10 IN=2,NL
            READ(9,510) XLOCS,YLOCS
            XLOC(I,IN)=XLOCS
            YLOC(I,IN)=YLOCS
10       CONTINUE
         XLOC(I,1)=XIC(I,1)
         YLOC(I,1)=YIC(I,1)
         IDIR(I,1)=0
         NL=N(I)
         NUM=2
         DO 100 J=1,NL
            XL=XLOC(I,J+1)-XLOC(I,J)
            YL=YLOC(I,J+1)-YLOC(I,J)
            DIST=SQRT(XL**2+YL**2)
            Y=ABS(YL)
            Z=Y/XL
            ANGL=ATAN(Z)
            DEG=ANGL*57.2958
            IF(J.EQ.1) GO TO 50
               XLN=(CST-EXTRA)*COS(ANGL)
               DIST=(DIST+EXTRA)-DST
               YLN=(CST-EXTRA)*SIN(ANGL)
               XIC(I,NUM)=XIC(I,NUM-1)+XLN+XLE
               IF(YL.GT.0.) GO TO 20
                  YLN=-YLN
20             YIC(I,NUM)=YIC(I,NUM-1)+YLN+YLE
               IF(YL.GT.0.) GO TO 30
                  IDIR(I,NUM)=-IFIX(DEG)
                  GO TO 40
30             IDIR(I,NUM)=IFIX(DEG)
```

```
 40             NUM=NLM+1
 5C         XLN=CST*CCS(ANGL)
            YLN=OST*SIN(ANGL)
            IF(YL.GT.O.) GO TO 60
                YLN=-YLN
 6C         IF(DIST.LT.CST) GO TO 9C
                XIC(I,NUM)=XIC(I,NUM-1)+XLN
                YIC(I,NUM)=YIC(I,NUM-1)+YLN
                IF(YL.GT.C.) GO TO 7C
                    ICIR(I,NUM)=-IFIX(CEG)
                  GO TC 8C
 70             ICIR(I,NUM)=IFIX(DEG)
 80             CIST=CIST-CST
                NLM=NLM+1
                GO TO 6C
 90         EXTRA=CIST
            XLE=EXTRA*COS(ANGL)
            YLE=EXTRA*SIN(ANGL)
            IF(YL.GT.O.) GC TO 100
                YLE=-YLE
100       CCNTINUE
11C CCNTINUE
C
500 FOFMAT(38X,I2)
510 FORMAT(12X,F8.1,12X,F8.1)
    RETURN
    ENC
C
    SLBROUTINE LAMCA(I,J,PCTVIS,CETRAT,PK)
C
C ***  SLBRCUTINE LAMCA IN CONJUCTICN WITH THE LCS ROUTINE CCMPUTES
C      THE DETECTION FATE(CETRAT) CF TARGET J BY THE OBSERVER I GIVEN
C      THE PERCENT CF TARGET VISIBLE (PCTVIS) TO THE OBSERVER.
C
    CCMMON /CPF1/ IPFCIR(6),ISECWC(6),MVTDIR(6),X(6),Y(6),SPD(6)
    TCFACT=1.C
    ZEROL=C.00001
    FAI=3.14159
  7 C=(ISECWC(I)*PAI/18C.C)/2.0
    BEE=(1.0/(2.0*(SIN(D)-D*CCS(D))))
    IF(ABS(BEB).LT.ZERCL) BBB=0.0
    AAA=(-BBE)*COS(D)
    IF(AES(AAA).LT.ZERCL) AAA=0.0
    CTANG=ATAN2((Y(J)-Y(I)),(X(J)-X(I)))
    IF(CTANG.LT.-PAI/2.AND.CTANG.GT.-PAI) CTANG=2*PAI+CTANG
    FD=IPRCIF(I)*PAI/180.0
    IF((PD*CTANG).GE.C.O) GOTC 1
    IF(PO.LT.C.O) GCTC 9
    ANGLE=2*FAI+OTANG-FC
    GOTO 10
  9 ANGLE=2*FAI+PC-CTANG
 10 IF(ANGLE.GT.PAI) ANGLE=2*FAI-ANGLE
    GOTC 2
  1 ANGLE=AES(FO-CTANG)
  2 IF(ANGLE.GT.D) GC TO 3
    CLP=PO+C
    CLCW=PD-C
    ANGLFT=CTANG+(15.C*PAI/18C.)
    IF(ANGLFT.GT.DUP) ANGLFT=CUP
    ANGLRT=OTANG-(15.*FAI/180.)
    IF(ANGLRT.LT.DLCW) ANGLRT=OLOW
    FK=EBB*AES(ABS(SIN(ANGLFT))-AES(SIN(ANGLRT)))+AAA*(ANGLFT-
   *ANGLRT)
    IF(PK.LT.C.O) GO TC 3
    IF(PK.GT.1.O) GO TC 5
    GO TO 8
  3 PK=0.0
    DETRAT=0.C
    GC TO 6
  5 PK=1.0
  8 RANGE=SQRT((X(J)-X(I))**2+(Y(J)-Y(I))**2)
    RR=0.001*RANGE/PCTVIS
```

```
      TOANG=ATAN2((Y(I)-Y(J)),(X(I)-X(J)))
      AD=MVTDIR(J)*PAI/180.0
      HORVEL=ABS(SPD(J)*SIN(TOANG-AD))
      HORVEL=HORVEL*1609.3/3600.0
      DENOM=1.453+TCFACT*(0.5978+2.188*(RR**2)-0.5038*HORVEL)
      IF(DENOM.LE.ZERO) DENOM=ZERO
      DETRAT=0.003+1.088/DENOM
      DETRAT=DETRAT*FK
    6 RETURN
      END
C
      SUBROUTINE ELEV(X,Y,THAC)
C
C *** SUBROUTINE ELEV DETERMINES THE TERRAIN ELEVATION FOR A GIVEN
C     SET OF X, Y COORDINATES. THIS FUNCTION IS USED IN CONJUNCTION
C     WITH THE LOS SUBROUTINE IN COMPUTING LINE-OF-SIGHT BETWEEN
C     OBSERVER AND TARGET.
C
      COMMON /HILLS/ XC(100),YC(100),PEAK(100),ANGH(100),SPRD(100)
      COMMON /HILLS/ ECC(100),PXX(100),PYY(100),PXY(100),BASE
      COMMON /HILLS/ NHILLS
      COMMON /GRID/ LST(5,4),NHL(5,4),LISTH(150),KHREP(150),KTREP
      COMMON /GRID/ LSTC(5,4),NC(5,4),LISTC(400),KCREP(150)
      DATA GSIZE/1000./
C*** FUNCTION TO COMPUTE TERRAIN ELEVATION FOR GIVEN X, Y COORDINATES.
      ZMAX=BASE
      IX=1+IFIX(X/GSIZE)
      IY=1+IFIX(Y/GSIZE)
      IF(NHL(IX,IY).EQ.0) GO TO 150
      LS=LST(IX,IY)
      LEND=LS+NHL(IX,IY)-1
      DO 100 L=LS,LEND
      I=LISTH(L)
      QX=X-XC(I)
      QY=Y-YC(I)
      QXSQ=QX*QX
      QYSQ=QY*QY
      QXY=QX*QY
      FACTOR=PXX(I)*QXSQ+PYY(I)*QYSQ+PXY(I)*QXY
      IF(FACTOR.LT.-3.) GO TO 100
      HT=PEAK(I)*EXP(FACTOR)
      IF(HT.LE.ZMAX) GO TO 100
      ZMAX=HT
  100 CONTINUE
  150 THAC=ZMAX
      RETURN
      END
C
      SUBROUTINE STOCH(I,RANGE,A)
C
C *** SUBROUTINE STOCH DETERMINES THE ATTRITION COEFFICIENTS WHEN
C     A USER HAS SELECTED A STOCHASTIC ATTRITION OPTION. THE CALCULATION
C     IS A FUNCTION OF THE ORIGINAL STOCHASTICALLY DETERMINED ATTRITION
C     COEFFICIENT AS WELL AS A FUNCTION OF RANGE.
C
      COMMON /GRP6/ ALPHA(6)
      COMMON /GRP3/ NBU,NRU,FL(6),FO(6),NOI(3),XIC(3,200),YIC(3,200),
     *ICIR(3,200),AVSP,ISPD
     *,IUSTAT(6),II(6),LCST(6,6),VISFRA,VISFRB,SIZETK,
     *SIZETW,NT(6),NF(6),SRF,DISMAX,
     *NLCSC(6,6),VISFR(6,6),RMINTK,RMXTK,RMINTW,RMXTW,OP,TOWER,LVAFR,
     *PTT(3,3),RF,PCA(6,6),APDA(6,6),LOA(6,6),NA(6),CFL(6),POL(6)
      IF(I.EQ.2) GO TO 10
      A=ALPHA(I)*((1.0-RANGE/RMXTW)**2)
      GO TO 20
   10 A=ALPHA(I)*((1.0-RANGE/RMXTK)**2)
   20 RETURN
       END
C
      SUBROUTINE ETK(I,RANGE,T)
C
C *** SUBROUTINE ETK COMPUTES THE EXPECTED TIME FOR A GIVEN FIRER TO
```

```
C      KILL A GIVEN TARGET. THE CALCULATION IS A FUNCTION OF RANGE,
C      TIME OF FLIGHT FOR A ROUND AND HIT AND KILL PROBABILITIES FOR
C      THE FIRING WEAPON SYSTEM. IT IS A NUMBER THAT IS USED IN THE
C      COMPUTATION OF THE DETERMINISTIC ATTRITION COEFFICIENTS.
C
       COMMON /GRP2/ TA(2),TI(2),TH(2),TM(2),TF1(2),TF2(2),TF3(2),
      *P(2,6),PHH(2,6),PHM(2,6),PKH(2,6),TF(2)
       IF(I.EQ.2) GO TO 5
           TF(I)=TF1(I)
           GOTO 6
     5 IF(RANGE.GT.1000.0) GO TO 7
           TF(I)=TF1(I)-(TF1(I)*(1000.0-RANGE)/1000.0)
           GO TO 6
     7 IF(RANGE.GT.2000.0) GO TO 8
           TF(I)=TF2(I)-((TF2(I)-TF1(I))*(2000.0-RANGE)/1000.0)
           GO TO 6
     8 TF(I)=TF3(I)-((TF3(I)-TF2(I))*(3000.0-RANGE)/1000.0)
     6 J=(RANGE+250.0)/500.0
       IF(J.GT.6) J=6
           T=TA(I)+TI(I)-TH(I)+((TH(I)+TF(I))/PKH(I,J))+((TM(I)+TF(I))/
      *PHM(I,J))*((1.0-PHH(I,J))/PKH(I,J)+PHH(I,J)-P(I,J))
       RETURN
       END
C
       SUBROUTINE SORT(I,M)
C ***  SUBROUTINE SORT IS USED TO SORT TARGETS IN ASCENDING RANGE
C      ORDER. THIS IS USED TO DETERMINE THE PRIORITY OF A TARGET
C      FOR FIRE ALLOCATION.
C
       COMMON /GRP5/ LOT(6,6),ROT(6,6)
       DO 10 J=1,M
           IF(ROT(I,M).GE.ROT(I,J)) GO TO 10
               R=ROT(I,J)
               NN=LOT(I,J)
               ROT(I,J)=ROT(I,M)
               LOT(I,J)=LOT(I,M)
               ROT(I,M)=R
               LOT(I,M)=NN
    10 CONTINUE
       RETURN
       END
C
       SUBROUTINE KOVER(ZO,TMACT,SIZET,ZT,S,HTS,ZS,VISFRT)
C ***  SUBROUTINE KOVER DETERMINES WHAT PORTION OF A PARTICULAR TARGET
C      IS COVERED BY THE TERRAIN BETWEEN THE TARGET AND OBSERVER.
C      THIS NUMBER IS USED IN THE DETECTION AND ATTRITION COMPUTATION.
C
       IF(S.EQ.0.) GO TO 10
           IF(HTS.GE.ZS) GO TO 20
               HEXT=ZO+(HTS-ZO)/S
               EVIST=AMAX1(HEXT,TMACT)
               IF(EVIST.GE.ZT) GO TO 20
                   IF(EVIST.LE.ZT-SIZET) RETURN
                       VIS=(ZT-EVIST)/SIZET
                           IF(VIS.LT.VISFRT) VISFRT=VIS
                               RETURN
 10    IF(HTS.LT.ZO) RETURN
 20    VISFRT=0.0
       RETURN
       END
C
       SUBROUTINE LOS(XA,YA,TMACA,TMICA,SIZEA,XB,YB,TMACB,TMICB,SIZEB,
      *LATCB,LBTCA,VISFRA,VISFRB)
C ***  THIS SUBROUTINE WAS WRITTEN BY PROFESSOR JAMES HARTMAN, NAVAL
C      POSTGRADUATE SCHOOL.  IT COMPUTES A PERCENT OF A TARGET VISIBLE
C      TO A PARTICULAR OBSERVER, GIVEN THE COORDINATES OF BOTH
C
       COMMON /HILLS/ XC(100),YC(100),PEAK(100),ANGH(100),SPRD(100)
       COMMON /HILLS/ ECC(100),PXX(100),PYY(100),PXY(100),BASE
       COMMON /HILLS/ NHILLS
       COMMON /COVER/ CXC(150),CYC(150),CPEAK(150),CPXX(150),CPYY(150)
       COMMON /COVER/ CPXY(150),NCVELS
```

```
      COMMON /COUNTR/KH, KHW, KV, KN, KGRS, KELL, KINT
      COMMCN /GRID/ LST(5,4),NHL(5,4),LISTH(150),KHREP(15C),KTREP
      COMMON /GRID/ LSTC(5,4),NC(5,4),LISTC(400),KCREP(150)
      DIMENSICN IGX(10C),IGY(10C),IEL(100),CS1(100),CS2(100)
      DATA GSIZE/100C./
C*** SUBROUTINE TO COMPUTE FRACTION VISIBLE FOR OBSERVER TARGET PAIRS
      VISFRA=1.
      VISFRB=1.
      XBA=XB-XA
      YBA=YB-YA
      IF((XBA.EQ.0.).AND.(YBA.EQ.0.)) RETURN
        IF(SIZEA+TMICA.LE.0.) GO TO 510
        IF(SIZEB+TMICB.LE.0.) GO TC 510
        IF(TMICA.LT.0.) VISFRA=1.0+TMICA/SIZEA
        IF(TMICB.LT.C.) VISFRB=1.0+TMICB/SIZEB
          ZA=TMACA + TMICA + SIZEA
          ZB=TMACB + TMICB + SIZEB
          KTREP=KTREP+1
          ZBA=ZB-ZA
          XBASC=XBA*XBA
          YBASC=YBA*YBA
          XYBA=XBA*YBA
          TWOXBA=2.*XBA
          TWOYBA=2.*YBA
C*** COMPUTE GRID SQUARES CROSSED BY A TO B LINE
      NGRSQ=0
      IF(XBA) 110,95,100
95        XBA=0.1
10C       ISGX=-1
          XINC=GSIZE/XBA
            GO TO 12C
11C       ISGX=1
          XINC=-GSIZE/XBA
12C   IF(YBA)  140,125,13C
125       YBA=C.1
13C       ISGY=-1
          YINC=GSIZE/YBA
            GO TO 15C
14C       ISGY=1
          YINC=-GSIZE/YBA
15C   IX=1+IFIX(XB/GSIZE)
      IY=1+IFIX(YB/GSIZE)
      XNEXT=GSIZE*(FLOAT(IX)+0.5*(ISGX-1.))
      YNEXT=GSIZE*(FLOAT(IY)+0.5*(ISGY-1.))
      XSTEP=(XB-XNEXT)/XBA
      YSTEP=(YB-YNEXT)/YBA
16C   NGRSQ=NGRSC+1
      IGX(NGRSC)=IX
      IGY(NGRSC)=IY
      IF((XSTEP.GT.1.).AND.(YSTEP.GT.1.)) GO TO 200
      IF(XSTEP-YSTEP) 17C,18C,190
170       IX=IX +ISGX
          XSTEP=XSTEP+XINC
            GO TC 16C
18C       IX=IX+ISGX
          XSTEP=XSTEP+XINC
19C       IY=IY+ISGY
          YSTEP=YSTEP+YINC
            GO TC 16C
20C   KGRS=KGRS+NGRSC
C GRID SQUARE LIST NCW COMPLETE IN IGX, IGY WITH NGRSQ ENTRIES
C
C*** FIND WHICH COVER ELLIPSES TOUCH THE A TC B LINE,
C*** CHECK ELEVATICNS AT S1 AND S2 FCR EACH SUCH ELLIPSE
      NELS=0
      CHTMAX=C.
      IF(NCVELS.EQ.C) GOTO 270
        DO 26C K=1,NGRSC
          IX=IGX(K)
          IY=IGY(K)
          N=NC(IX,IY)
          IF(N.EQ.0) GC TO 26C
```

```
                    LS=LSTC(IX,IY)
                    LEND=LS+N-1
                    DO 250 L=LS,LEND
                       KELL=KELL+1
                       IC=LISTC(L)
                       IF(KCREF(IC).EQ.KTREF) GO TO 250
                          KCREF(IC)=KTREF
                          RX=XA-CXC(IC)
                          RY=YA-CYC(IC)
                          PPXX=CPXX(IC)
                          PPYY=CPYY(IC)
                          PPXY=CPXY(IC)
                          AA=PPXX*XBASQ+PPYY*YBASQ+PPXY*XYBA
                        BB=PPXX*TWOXBA*RX+PPYY*TWOYBA*RY+PPXY*(RX*YBA+RY*XBA)
                          CC=PPXX*RX*RX+PPYY*RY*RY+PPXY*RX*RY-1.0
                          ARG=BB*BB-4.0*AA*CC
                          IF(ARG.LE.0.) GO TO 250
                             SQ=SQRT(ARG)
                             S1=-(BB+SQ)/(2.0*AA)
                             S2=(SQ-BB)/(2.0*AA)
                             IF(S1.GE.1.) GO TO 250
                             IF(S2.LE.0.) GO TO 250
                             IF(S1.LE.0.)  GO TO 510
                             IF(S2.GE.1.) GO TO 510
C*** CHECK LOS AT S1 AND S2
                 KINT=KINT+1
                 CPK=CPEAK(IC)
                 XS=XA+S2*XBA
                 YS=YA+S2*YBA
                 CALL ELEV(XS,YS,HTS)
                 HTS=HTS+CPK
                 ZS=ZA+S2*ZBA
                 IF(LATOB.EQ.0) GO TO 210
                    CALL KOVER(ZA,TMA(B,SIZEB,ZB,S2,HTS,ZS,VISFRB)
                    IF(VISFRB.LE.0.) GO TO 510
210              IF(LBTOA.EQ.0) GO TO 220
                    S=1.-S2
                    CALL KOVER(ZB,TMA(A,SIZEA,ZA,S,HTS,ZS,VISFRA)
                    IF(VISFRA.LE.0.) GO TO 510
220              XS=XA+S1*XBA
                 YS=YA+S1*YBA
                 CALL ELEV(XS,YS,HTS)
                 HTS=HTS+CPK
                 ZS=ZA+S1*ZBA
                 IF(LATOB.EQ.0) GO TO 230
                    CALL KOVER(ZA,TMA(B,SIZEB,ZB,S1,HTS,ZS,VISFRB)
                    IF(VISFRB.LE.0.) GO TO 510
230              IF(LBTOA.EQ.0) GO TO 240
                    S=1.0-S1
                    CALL KOVER(ZB,TMA(A,SIZEA,ZA,S,HTS,ZS,VISFRA)
                    IF(VISFRA.LE.0.) GO TO 510
240              NELS=NELS+1
                 IEL(NELS)=IC
                 CS1(NELS)=S1
                 CS2(NELS)=S2
                 IF(CPK.GT.CHTMAX) CHTMAX=CPK
250              CONTINUE
260     CONTINUE
C*** ALL ELLIPSES CHECKED
C*** START ON THE HILLS
  270 DO 600 K=1,NGRSQ
            IX=IGX(K)
            IY=IGY(K)
            IF(NHL(IX,IY).EQ.0) GO TO 600
            LS=LST(IX,IY)
            LEND=LS+NHL(IX,IY) -1
           DO 500 L=LS,LEND
              I=LISTH(L)
              IF(KHREF(I).EQ.KTREF) GO TO 500
              KHREF(I)=KTREF
C*** PROCESSING FOR HILL I STARTS HERE
                 KH=KH+1
```

```
C*** COMPUTE W =TOP OF THIS HILL ALONG G-T LINE
C
               TRX=XA-XC(I)
               TRY=YA-YC(I)
               TPXX=PXX(I)
               TPYY=PYY(I)
               TPXY=PXY(I)
               FQ=TWOXBA*TPXX*TRX+TWOYBA*TPYY*TRY+TPXY*(TRX*YBA+TRY*XBA)
               GQ=TPXX*XBASQ+TPYY*YBASQ+TPXY*XYBA
               IF(GQ .EQ.0.)  GO TO 500
               W=-FQ/(2.*GQ)
               IF(ABS(W).GT.5.) GO TO 500
               FSQ=FQ*FQ
               EQ=TPXX*TRX*TRX+TPYY*TRY*TRY+TPXY*TRX*TRY
C
               POWER=EQ-FSQ/(4.*GQ)
               IF(POWER .LT. -3.) GO TO 500
               HHW=PEAK(I)*EXP(POWER)
               KHW=KHW+1
               IF(HHW.LE.BASE) GO TO 500
               ZW=ZA+W*ZBA
               IF((W.LT.0.).OR.(W.GT.1.)) GO TO 300
               IF(HHW .GE. ZW) GO TO 510
               CVHTW=0.
               IF(NELS.EQ.0) GO TO 300
               DO 280 M=1,NELS
                  IF((CS1(M).GE.W).OR.(CS2(M).LE.W)) GO TO 280
                  IC=IEL(M)
                  IF(CVHTW.LT.CPEAK(IC))  CVHTW=CPEAK(IC)
280            CONTINUE
               IF((HHW+CVHTW).GE.ZW)  GO TO 510
300            IF(HHW+CHTMAX.LT.AMIN1(ZA-SIZEA,ZB-SIZEB)) GO TO 500
C*** IF WE GET TO HERE THEN NEED TO FIND LOWEST SIGHT LINE OVER HILL
C*** NEWTON ITERATION A TO B GIVING VISFRB
               IF(LATOB.EQ.0) GO TO 400
               KV=KV+1
               V=W
               HHV=HHW
               NCT=0
               FV=FQ*V
               TWOGV=2.*GQ*V
330            FCNV=ZA+HHV*(TWOGV*V+FV-1.)
               KN=KN+1
               FACTOR=(TWOGV*TWOGV+2.*(GQ+TWOGV*FQ)+FSQ)
               DFCNV=HHV*V*FACTOR
               IF(ABS(DFCNV) .LT.1.E-10) GO TO 350
               V=V-FCNV/DFCNV
               FV=FQ*V
               TWOGV=2.*GQ*V
               POWER = EQ+FV+GQ*V*V
               IF(POWER .LT. -3.) GO TO 400
               HHV=PEAK(I)*EXP(POWER)
               DHHV=HHV*(FQ+TWOGV)
               ELV=ZA+DHHV*V
               IF (ABS(HHV-ELV) .LT.1.) GO TO 350
               NCT=NCT+1
               IF (NCT.LT.10) GO TO 330
350            IF((V.LT.0.).OR.(V.GT.1.)) GO TO 400
               CVHTV=0.
               IF(NELS.EQ.0) GO TO 390
               DO 380 M=1,NELS
                  IF((CS1(M).GE.V).OR.(CS2(M).LE.V))GO TO 380
                  IC=IEL(M)
                  IF(CVHTV.LT.CPEAK(IC)) CVHTV=CPEAK(IC)
380            CONTINUE
390            HTV=HHV+CVHTV
               ZV=ZA+V*ZBA
               CALL KOVER(ZA,TMACB,SIZEB,ZB,V,HTV,ZV,VISFRB)
               IF (VISFRB.LE.0.) GO TO 510
C*** NEWTON ITERATION B TO A GIVING VISFRA
               IF(ABS(V).GT.5.)GO TO 400
400            IF(LBTOA.EQ.0) GO TO 500
```

```
      KV=KV+1
      V=W
      VM1=V-1.
      HHV=HHW
      NCT=0
      FV=FQ*V
      TWOGV=2.*GQ*V
430   FCNV=ZB+HHV*((FQ+TWOGV)*VM1-1.)
      KN=KN+1
      FACTOR=(TWOGV*TWOGV+2.*(GQ+TWOGV*FQ)+FSQ)
      DFCNV=HHV*VM1*FACTOR
      IF(ABS(DFCNV) .LT.1.E-10) GO TO 450
      V=V-FCNV/DFCNV
      IF(ABS(V).GT.5.)GO TO 500
      VM1=V-1.
      FV=FQ*V
      TWOGV=2.*GQ*V
      POWER = EQ+FV+GQ*V*V
      IF(POWER .LT. -3.) GO TO 500
      HHV=PEAK(I)*EXP(POWER)
      DHHV=HHV*(FQ+TWOGV)
      ELV=ZB+DHHV*VM1
      IF (ABS(HHV-ELV) .LT.1.) GO TO 450
      NCT=NCT+1
      IF (NCT.LT.10) GO TO 430
450   IF((V.LT.0.).OR.(V.GT.1.)) GO TO 500
      CVHTV=0.
      IF(NELS.EQ.0) GO TO 490
      DO 480 M=1,NELS
         IF((CS1(M).GE.V).OR.(CS2(M).LE.V))GO TO 480
         IC=IEL(M)
         IF(CVHTV.LT.CPEAK(IC)) CVHTV=CPEAK(IC)
480   CONTINUE
490   HTV=HHV+CVHTV
      ZV=ZA+V*ZBA
      S=-VM1
      CALL KOVER(ZB,TMACA,SIZEA,ZA,S,HTV,ZV,VISFRA)
      IF (VISFRA.LE.0.) GO TO 510
500     CONTINUE
600   CONTINUE
      RETURN
510   VISFRA=0.
      VISFRB=0.
      RETURN
      END
```

# APPENDIX C

## COMPLETE INPUT DATA SET

for the

## SMALL-UNIT AMPHIBIOUS OPERATION COMBAT MODEL

The small-unit amphibious operation combat model consists of two phases of combat, ship-to-shore and land combat, and requires data input for each of these phases. The data set that follows is divided into two parts: the first part consists of all data used as input for the ship-to-shore phase of combat, and the second part consists of all data used as input for the land combat phase of combat. The input data set was designed to be self-documenting in that the input variable names or descriptive phrases are listed alongside the data being used as input to the model. The purpose of this documentation was to assist the user in associating the input data with their respective input variables. A complete input data set follows.

```
            IPRINT = 1     0 FOR EACH TIME STEP & 1 FOR END OF BATTLE.
LVA'S    SPDMAX = 40.00 SPDMIN =10.5 HTMAX = 1.7 HTMIN = 0.6 WIDTH = 3.533
              TTS = 10.      LENGTH OF EACH TIME STEP IN SECONDS.
TANK MAX RANGE =   1500. ATGM MAX RANGE =   2000. ATGM MIN RANGE =   200.
            TARTM = 15.      SARTM = 30.   TVEL  = 350. SVEL  = 350.
TSIGV = 25.        500.        1000.        2000.        5000.      10000.          0.
         2.          5.          20.          25.          25.
TSIGH = 25.        500.        1000.        2000.        5000.      10000.          0.
         2.          5.          20.          25.          25.
TMENF = 25.        500.        1000.        2000.        5000.      10000.          0.
         1.          5.          10.          15.          15.
SSIGV = 25.        250.         500.        1000.        2500.       5000.      10000.
         0.          5.          7.5          14.         15.5         17.         20.
SSIGH = 25.        250.         500.        1000.        2500.       5000.      10000.
         0.          5.          7.5          14.         15.5         17.         20.
DEF. WEIGHTS ASSIGNED TO WAVE ONE =          2. AND WAVE TWO =       1.
     NO. OF LVA PER WAVE = 25.            20.          15.          10.          5.
 SHORE DEF. TANK ASSETS =                  10. ATGM ASSETS =        10.
ATTRIT COEF. FOR AGGRESSOR FORCE FIRE: ALPHA1= 0.00006     ALPHA2  = 0.00008
ATTRIT COEF. FOR DEFENSIVE FORCE FIRE: BETA1 = 0.0007      BETA2   = 0.0009
      AIMED FIRE ATTRIT COEF.:        WBETA(1) =  0.0005   WBETA(2) = 0.0007
           GAINL =  0.32
           GAMMA =  50.0          DELTA = 100.0
     NO. OF HILLS IN TERRAIN MODEL =  46
             BASE = 0.0
HILL DATA:XC= 2000.  YC= 1100. PEAK= 170. ANGH=   0.1 SPRD= 999.9   ECC:  8.0
              1800.      2200.       150.        30.         350.          2.0
              2000.      1900.       150.       130.         300.          2.
              2400.      1400.       150.         0.1        300.          2.5
              2450.      1700.       130.        80.         500.          2.2
              2700.      1800 .      138.        90.         500.          2.2
              3200.      1650.       140.       150.         600.          3.
              4300.      1300.       130.       160.         400.          3.5
              3750.      1750.       150.         0.1        660.          3.6
              4150.      1600.       150.       160.         550.          3.
              3200.      2150.       130.        25.         500.          1.5
              4600.      1700.       170.        45.         300.          2.5
              4800.      1500.       170.         0.1        300.          2.5
              2200.      2600.       170.        90.         350.          1.8
              2400.      2850.       150.       120.         300.          1.8
              3100.      2700.       150.       150.         350.          2.
              2500.      2400.       150.         0.1        250.          1.0
              2650.      2850.       150.       160.0        400.          3.0
              2700.      2600.       150.       130.         270.          1.8
              3800.      2200.       150.         0.1        220.          1.5
              4500.      2600.       150.        90.         280.          1.3
              3600.      2800.       150.       145.         500.          2.5
              2700.      3300.       190.        25.         350.          2.0
              3000.      3300.       170.        15.         400.          2.5
              3150.      3750.       130.         0.1        350.          2.5
              3750.      3200.       150.        10.         850.          5.0
              3800.      3800.       150.         0.1        650.          3.
              3600.      3600.       150.       160.         320.          2.0
              4150.      3950.       170.        30.         220.          2.2
              1650.      2100.       150.        30.         300.          2.0
              2250.      2100.       180.       150.         320.          1.2
              2200.      1700.       180.        80.         150.          1.5
              2800.      1400.       150.       165.         500.          2.7
              3800.      2650.       150.        20.         400.          2.5
              4150.      3000.       130.       160.         300.          1.7
              4450.      3150.       130.       140.         350.          2.5
              4850.      3600.       150.        45.         400.          1.8
              4500.      4000.       150.        60.         450.          2.
              4850.      3450.       150.       150.         440.          1.8
              4900.      3000.       130.        45.         250.          1.5
              4700.      2400.       150.        50.         400.          2.5
              4900.      2000.       130.         0.1        250.          1.5
              2500.      1100.       170.         0.1        950.          8.
              3350.      4300.       150.        45.         450.          2.5
              4000.      2200.       150.        45.         280.          2.
              3900.      2200.       150.         0.1        300.          3.5
     LST(5,4) =    0      0     0      0     0      0     1      7     18    27
```

```
NHL(5,4) =   0   33   39   53   62    0   74   77   83   93
             0    0    0    0    0    0    6   11    9    6
             0    6   14    9   12    0    3    6   10    9

NO. OF HILLS TOTAL =  101
LISTH(I) =   1    2    3   30    4   43    1    3    4    5
             6   32   33    7   11   31   43    1    6    7
             8    9   10   11   33   43   10   12   13    9
             8   42    2   14   30   23   15    3   14   15
            16   17   18   19   20    3    6   23   11    7
             2   31   11   16   20   22   34   35   44   45
            46   20   21   22   12   34   35   36   40   41
            42   45   46   14   23   15   23   24   25   15
            26   14   25   26   27   28   29   24   22   23
            35   44   26   27   29   35   36   37   38   39
            40

NCVELS =  0
```

```
   ATTRIT VAR =    0     CSEED =    143257.0  (FOR AGGRESSOR FORCES)
BETA DIST. INPUT PARAMETERS:   PP =            7.0  QQ =          21.0
   ATTRIT VAR =    0     CSEED =    123457.0  (FOR DEFENSIVE FORCES)
BETA DIST. INPUT PARAMETERS:   PD =           21.0  QD =           7.0
NO. DEF UNITS =  03   NO. ATK UNITS = 03
 RMINTK = 0000.0    RMXTK = 2500.0 RMINTW   = 0500.0    RMXTW = 4000.0
  TYPE OF ROUTE = 1    VEHICLE SPEED = 4
 XIC(1,1) =   2000.0  YIC(1,1) =   1900.0
              1900.0               2400.0
              1500.0               2100.0
  NO. OF NODES FOR ROUTE 1 =           01
 XLOC(1,1)=   5000.0  YLOC(1,1)=   2500.0     FOR NODE 1 OF ROUTE 1
  NO. OF NODES FOR ROUTE 2 =           01
 XLOC(2,1)=   4900.0  YLOC(2,1)=   2150.0     FOR NODE 1 OF ROUTE 2
  NO. OF NODES FOR ROUTE 3 =           02
 XLOC(3,1)=   2200.0  YLOC(3,1)=   1700.0     FOR NODE 1 OF ROUTE 3
 XLOC(3,2)=   4800.0  YLOC(3,2)=   1750.0     FOR NODE 2 OF ROUTE 3
DEF UNIT X =  3800.0            Y =  2700.0 FORCE10.0  DIR. 190 WIDTH 120
    I         3800.0                 2300.0 LEVEL 5.0    OF  190    OF  120
LOCATION      3600.0                 1700.0      10.0  FIRE 180  SRCH 120
    ALT. POS. VAR. 0      BREAK PT   0500.0 NO. TIME STEPS FOR MOVE      4
      XA(1) = 4500.0        YA(1) =  3800.0 FOR ALT. POS. 1
      XA(2) = 4500.0        YA(2) =  2700.0  =    =     =   2
          X = 4600.0            Y =  1600.0  =    =     =   3
     0.60         0.70        0.65        0.85
     0.65         0.90        0.85        0.90
     0.60         0.85        0.85        0.80
     0.75         0.80        0.75        0.70
     0.60         0.70        0.65        0.65
     0.40         0.45        0.40        0.50
   P 0.85   PKH   0.85  PKH   0.75  PKH   0.70
     0.80         0.80        0.75        0.70
     0.75         0.75        0.70        0.60
     0.60         0.65        0.60        0.55
     0.45         0.50        0.50        0.35
     0.20         0.20        0.20        0.20
```

APPENDIX D

## BLANK INPUT DATA SET

for the

## SMALL-UNIT AMPHIBIOUS OPERATION COMBAT MODEL

The blank data set provided with the small-unit amphibious operation combat model was designed to assist the more familiar user of the model in the development of a new input data set to be analyzed by the model. It is patterned after the complete input data set listed in Appendix C providing input variable names or descriptive phrases to identify the locations of required input parameters. Underlining of the spaces following these descriptors is intended to serve as a guide for inputing values for the input variables in order that they will be compatible with the formatted read statements of the program. The blank input data set follows.

```
          IPRINT = _      0 FOR EACH TIME STEP & 1 FOR END OF BATTLE.
LVA'S   SPDMAX = __.__  SPDMIN = _.  HTMAX = _.  HTMIN = _.  WIDTH = _.___
             TTS = __.     LENGTH OF EACH TIME STEP IN SECONDS.
TANK MAX RANGE = ____. ATGM MAX RANGE = ____. ATGM MIN RANGE = ___.
           TARTM = __.     SAFTM = __.   TVEL = ___. SVEL = ___.
TSIGV = __.
TSIGH = __.
TMENH = __.
SSIGV = __.
SSIGH = __.
DEF. WEIGHTS ASSIGNED TO WAVE ONE =        __. AND WAVE TWO =     __.
        NO. OF LVA PER WAVE = __.
 SHORE DEF. TANK ASSETS =                    . ATGM ASSETS =
ATTRIT COEF. FOR AGGRESSOR FORCE FIRE: ALPHA1= _._____   ALPHA2 = _._____
ATTRIT COEF. FOR DEFENSIVE FORCE FIRE: BETA1 = _.____    BETA2  = _.____
      AIMED FIRE ATTRIT COEF.:      WBETA(1) = _.____  WBETA(2) = _.____
          GAINL =    _.__
          GAMMA =     .        DELTA =
     NO. OF HILLS IN TERRAIN MODEL = 40
             BASE = 0.0
```

| HILL DATA: XC= | YC= | PEAK= | ANGH= | SPRD= | ECC= |
|---|---|---|---|---|---|
| 2000. | 1100. | 170. | 0.1 | 999.9 | 8.0 |
| 1800. | 2200. | 150. | 30. | 350. | 2.0 |
| 2000. | 1900. | 150. | 130. | 300. | 2. |
| 2400. | 1400. | 150. | 0.1 | 300. | 2.5 |
| 2450. | 1700. | 130. | 80. | 500. | 2.2 |
| 2700. | 1800. | 138. | 90. | 500. | 2.2 |
| 3200. | 1650. | 140. | 150. | 600. | 3. |
| 4300. | 1300. | 130. | 160. | 400. | 3.5 |
| 3750. | 1750. | 150. | 0.1 | 660. | 3.6 |
| 4150. | 1600. | 150. | 160. | 550. | 3. |
| 3200. | 2150. | 130. | 25. | 500. | 1.5 |
| 4600. | 1700. | 170. | 45. | 300. | 2.5 |
| 4800. | 1500. | 170. | 0.1 | 300. | 2.5 |
| 2200. | 2600. | 170. | 90. | 350. | 1.8 |
| 2400. | 2850. | 150. | 120. | 300. | 1.8 |
| 3100. | 2700. | 150. | 150. | 350. | 2. |
| 2500. | 2400. | 150. | 0.1 | 250. | 1.0 |
| 2650. | 2950. | 150. | 160.0 | 400. | 3.0 |
| 2700. | 2600. | 150. | 130. | 370. | 1.8 |
| 3800. | 2200. | 150. | 0.1 | 230. | 1.5 |
| 4500. | 2600. | 150. | 90. | 280. | 1.3 |
| 3600. | 2800. | 150. | 145. | 500. | 2.5 |
| 2700. | 3300. | 190. | 25. | 350. | 2.0 |
| 3000. | 3300. | 170. | 15. | 400. | 2.5 |
| 3150. | 3750. | 130. | 0.1 | 350. | 2.5 |
| 3750. | 3200. | 150. | 10. | 850. | 5.0 |
| 3800. | 3800. | 150. | 0.1 | 650. | 3. |
| 3600. | 3600. | 150. | 160. | 320. | 2.0 |
| 4150. | 3950. | 170. | 30. | 220. | 2.2 |
| 1650. | 2100. | 150. | 30. | 300. | 2.0 |
| 2250. | 2100. | 180. | 150. | 220. | 1.2 |
| 2200. | 1700. | 180. | 80. | 150. | 1.5 |
| 2800. | 1400. | 150. | 165. | 500. | 2.7 |
| 3800. | 2650. | 150. | 20. | 400. | 2.5 |
| 4150. | 3000. | 130. | 160. | 300. | 1.7 |
| 4450. | 3150. | 130. | 140. | 350. | 2.5 |
| 4850. | 3600. | 150. | 45. | 400. | 1.8 |
| 4500. | 4000. | 150. | 60. | 450. | 2. |
| 4850. | 3450. | 150. | 150. | 440. | 1.8 |
| 4900. | 3000. | 130. | 45. | 250. | 1.5 |
| 4700. | 2400. | 150. | 50. | 400. | 2.5 |
| 4900. | 2000. | 130. | 0.1 | 250. | 1.5 |
| 2500. | 1100. | 170. | 0.1 | 950. | 8. |
| 3350. | 4300. | 150. | 45. | 450. | 2.5 |
| 4000. | 2200. | 150. | 45. | 280. | 2. |
| 3900. | 2200. | 150. | 0.1 | 300. | 3.5 |

```
LST(5,4) =  0   0   0   0   0   0   1   7   18   27
```

```
                   0    33    39    53    62     0    74    77    83    93
NHL(5,4)  =        0     0     0     0     0     0     6    11     9     6
                   0     6    14     5    12     0     3     6    10     9
NO. OF HILLS TOTAL =                   101
LISTH(I)  =        1     2     3    30     4    43     1     3     4     5
                   6    32    33     7    11    21    43     1     6     7
                   8     9    10    11    33    43    10    12    13     9
                   8    42     2    14    30    23    15     3    14    15
                  16    17    18    19    20     3     6    23    11     7
                   2    31    11    16    20    22    34    35    44    45
                  46    20    21    22    12    34    35    36    40    41
                  42    45    46    14    23    15    23    24    25    15
                  26    14    25    26    27    28    29    34    22    23
                  35    44    26    27    29    35    36    37    38    39
                  40
NCVELS  =                                0
```

```
     ATTRIT VAR =          CSEED =   -------._   (FCR AGGRESSCR FORCES)
BETA CIST. INFUT PARAMETERS:   FP =                 .     QQ =          .
     ATTRIT VAR =          CSEED =   -------._   (FCR DEFENSIVE FORCES)
BETA CIST. INFLT PARAMETERS:   FD =             --.--  QD =          -.-
NC. DEF UNITS =  __    NC. ATK UNITS =
 RMINTK =  ----.--    RMXTK =  ----.--   RMINTW   =  ----._     RMXTW =  ----._
  TYPE CF ROUTE =  _     VEHICLE SPEED =__
 XIC(1,1)  =   ----._   YIC(1,1)  =   ----._
               ----._                 ----._
                                      ----._
  NC. CF NODES FOR ROUTE    =
 XLCC(1,1)=    ----._   YLCC(1,1)=    ----._      FCR NODE 1 CF ROUTE 1
  NC. CF NODES FOR ROUTE    =
 XLOC(2,1)=    ----._   YLCC(2,1)=    ----._      FCR NODE 1 OF ROUTE 2
  NO. CF NODES FOR ROUTE    =
 XLCC(3,1)=    ----._   YLCC(3,1)=    ----._      FCR NODE 1 CF RCUTE 3
 XLOC(3,2)=    ----._   YLCC(3,2)=    ----._      FCR NODE 2 CF RCUTE 3
CEF UNIT X =   ----._              Y =   ----._ FCRCE__._  DIR.  ---  WIDTH  ---
        I      ----._                    ----._ LEVEL__._   OF   ---   OF    ---
LOCATICN       ----._                    ----._            FIRE  ---  SRCH   ---
    ALT. POS. VAR. _     BREAK PT        ----._ NC. TIME STEPS FCR MOVE      ---
      XA(1) =  ----._      YA(1)  =      ----._ FCR ALT. POS. 1
      XA(2) =  ----._      YA(2)  =      ----._  =    =     =  2
          X =  4600.0          Y  =      ----._  =    =     =  3
     -.--         -.--         -.--         -.--
     -.--         -.--         -.--         -.--
     -.--         -.--         -.--         -.--
     -.--         -.--         -.--         -.--
     -.--         -.--         -.--         -.--
  P  -.--    PHF  -.--    PHM  -.--    PKH  -.--
     -.--         -.--         -.--         -.--
     -.--         -.--         -.--         -.--
     -.--         -.--         -.--         -.--
     -.--         -.--         -.--         -.--
     -.--         -.--         -.--         -.--
```

## APPENDIX E

## EXECUTIVE PROGRAM

## for the

## SMALL-UNIT AMPHIBIOUS OPERATION COMBAT MODEL

The combat model presented in this thesis has been provided with an EXEC program which is designed to set up and execute all of the necessary CMS commands for the running of the model. The EXEC program will automatically BROWSE the output listing of the model (AMPHIB1 LISTING) allowing the user to review immediately the results of the battle. A listing of the EXEC follows.

```
GLOBAL TXTLIB FORTMOD2 MOD2EEH IMSLSP NONIMSL CMSLIB
FILEDEF 05 DISK SEA DATA
FILEDEF 09 DISK LAND DATA
FILEDEF 06 DISK AMPHIB1 LISTING
LOAD AMPHIB (START)
BROWSE AMPHIB 1 LISTING
```

APPENDIX F

COMPUTER OUTPUT

for the

SMALL-UNIT AMPHIBIOUS OPERATION COMBAT MODEL

The computer output for the small-unit amphibious operation combat model was designed to be clear, concise, and identifiable to the user of the program. The combat model conducts two phases of combat: ship-to-shore and land combat. Therefore, the computer output was designed to report on each phase of combat. The computer output for each phase of combat begins with an initial information page which lists the input data provided by the user of the model. The initial information page serves as a record of the battle scenario analyzed by the model, as well as a check for the user to insure that the input data provided were read correctly by the model. In addition, a battle summary report is provided reporting on the status of both the aggressor and defender forces throughout both phases of combat. The computer output based upon the input data listed in Appendix C is as follows.

** INITIAL SHIP-TO-SHORE PHASE INFORMATION **

INITIAL FORCE STRENGTH

| WAVE | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| LVA | 25.0 | 20.0 | 15.0 | 10.0 | 5.0 |

DEF. TANK ASSETS = 10.0 DEF. ATGM ASSETS = 10.0

LVA ENGR SPECS

| SPDMAX | SPDMIN | HTMAX | HTMIN | WIC |
|---|---|---|---|---|
| 40.00 | 10.50 | 1.70 | 0.60 | 3.53 |

DEFENSIVE TACTICAL PARAMETERS

| | RANGE MAX | RANGE MIN | AIM-RELOAD TIME | PROJECTILE VELOCITY |
|---|---|---|---|---|
| TANK | 1500.0 | | 15.00 | 350.00 |
| ATGM | 2000.0 | 300.0 | 30.00 | 350.00 |

DEFENSIVE TACTICAL ALLOCATION WEIGHTS:
WAVE 1 = 2.00 WAVE 2 = 1.00

DEFENSIVE FORCE ATTRITION COEFFICIENTS

| | ALPHA*A | BETA*A |
|---|---|---|
| DT | 0.00006 | 0.00070 |
| DS | 0.00008 | 0.00090 |

AIMED FIRE ATTRITION RATE COEFFICIENTS FOR
DEFENSIVE TANK AND ATGM ASSETS

WBETA(1)=0.00050 WBETA(2)=0.00070

BREAKPOINT ASSUMPTION: 0.3*(TOTAL DEF FORCE)

DEFENDER ATTRITION LEVEL ALLOWING FOR LAND COMBAT
0.32*(TOTAL DEFENDER FORCE)

ARTY SUP FACTOR= 50.0 ERROR SUP FACTOR=100.0

DISPERSION DATA

| RANGE | TSIGV | RANGE | TSIGH | RANGE | TMEANH |
|---|---|---|---|---|---|
| 25.0 | 0.0 | 25.0 | 0.0 | 25.0 | 0.0 |
| 500.0 | 2.0 | 500.0 | 2.0 | 500.0 | 1.0 |
| 1000.0 | 5.0 | 1000.0 | 5.0 | 1000.0 | 5.0 |
| 2000.0 | 20.0 | 2000.0 | 20.0 | 2000.0 | 10.0 |
| 5000.0 | 25.0 | 5000.0 | 25.0 | 5000.0 | 15.0 |
| 10000.0 | 25.0 | 10000.0 | 25.0 | 10000.0 | 15.0 |

| RANGE | SSIGV | RANGE | SSIGH |
|---|---|---|---|
| 25.0 | 0.0 | 25.0 | 0.0 |
| 250.0 | 5.0 | 250.0 | 5.0 |
| 500.0 | 7.5 | 500.0 | 7.5 |
| 1000.0 | 14.0 | 1000.0 | 14.0 |
| 2500.0 | 15.5 | 2500.0 | 15.5 |
| 5000.0 | 17.0 | 5000.0 | 17.0 |
| 10000.0 | 20.0 | 10000.0 | 20.0 |

CURRENT STATUS OF WAVE I VARIABLE DEFINITIONS

0 - NOT ENGAGING
1 - LANDED
2 - UNDER FIRE BY ATGM
3 - UNDER FIRE BY TANK
4 - UNDER FIRE BY BOTH ATGM & TANK

```
***** THE SHIP-TO-SHORE PHASE BEGINS *****

BREAKPOINT REACHED AT TIME =  502.5 SECONDS

TIME= 502.5 SECONDS

WAVE   FORCE LEVEL  STATUS  LOST-PCT  TOTAL SURVIVING
  1      16.0000      1      0.360
  2      13.0000      1      0.350
  3      11.0000      1      0.267
  4      10.0000      1      0.0
  5       5.0000      0      0.0          55.00
TANK      0.0                1.000
ATGM      0.0                1.000          0.0
FINAL LVA SURVIVORS ASHORE=      55.000
LAND COMBAT STARTS WHILE SHORE COMBAT IS GOING ON

LAND COMBAT ATTACK TIME = 495.0 SECONDS
```

## ** INITIAL LAND COMBAT INFORMATION **

| UNIT | LOCATION X | Y | FORCE LEVEL |
|---|---|---|---|
| 1 | 2000.0 | 1900.0 | 18.0 |
| 2 | 1900.0 | 2400.0 | 18.0 |
| 3 | 1500.0 | 2100.0 | 18.0 |
| 4 | 3600.0 | 2700.0 | 10.0 |
| 5 | 3800.0 | 2300.0 | 5.0 |
| 6 | 3600.0 | 1700.0 | 10.0 |

ATTRITION IS STOCHASTIC

ROUTES DETERMINED BY USER

ATTACK VEHICLE SPEED IS 18.0 M.P.H.

BREAKPOINT DISTANCE IS 500.0 METERS

DEFENDER WILL MOVE TO ALTERNATE POSITIONS
ALTERNATE POSITIONS ARE:

| UNIT | X | Y |
|---|---|---|
| 4 | 4500.0 | 3800.0 |
| 5 | 4500.0 | 2700.0 |
| 6 | 4600.0 | 1800.0 |

ATK KILL PROBABILITIES

| RANGE | P | PHH | PHM | PKH |
|---|---|---|---|---|
| 500 | 0.60 | 0.70 | 0.65 | 0.85 |
| 1000 | 0.85 | 0.90 | 0.85 | 0.90 |
| 1500 | 0.80 | 0.85 | 0.85 | 0.80 |
| 2000 | 0.75 | 0.80 | 0.75 | 0.70 |
| 2500 | 0.60 | 0.70 | 0.65 | 0.65 |
| 3000 | 0.40 | 0.45 | 0.40 | 0.50 |

DEF. KILL PROBABILITIES

| RANGE | P | PHH | PHM | PKH |
|---|---|---|---|---|
| 500 | 0.85 | 0.85 | 0.75 | 0.70 |
| 1000 | 0.80 | 0.80 | 0.75 | 0.70 |
| 1500 | 0.75 | 0.75 | 0.70 | 0.60 |
| 2000 | 0.60 | 0.65 | 0.60 | 0.55 |
| 2500 | 0.45 | 0.50 | 0.50 | 0.35 |
| 3000 | 0.20 | 0.20 | 0.20 | 0.20 |

CURRENT STATUS OF UNIT I VARIABLE DEFINITIONS

0 - ALIVE NOT FIRING
1 - ALIVE AND FIRING
2 - KILLED
3 - MOVING

VEHICLE SPEED VARIABLE DEFINITIONS

1 - 9 MPH
2 - 12 MPH
3 - 15 MPH
4 - 18 MPH

***** THE LAND COMBAT PHASE BEGINS *****

**** DEFENSIVE FORCE IS ELIMINATED. END OF BATTLE.

TIME= 745 SECONDS

AGGRESOR UNIT INFORMATION

| UNIT | X | Y | FORCE LEVEL | STATUS | LOST-PCT | TARGETS |
|---|---|---|---|---|---|---|
| 1 | 2394.5 | 1978.9 | 0.0 | 2 | 1.000 | |
| 2 | 3744.3 | 2246.3 | 4.8 | 1 | 0.731 | 5 |
| 3 | 3324.7 | 1721.6 | 17.9 | 0 | 0.005 | |

DEFENSIVE UNIT INFORMATION

| UNIT | X | Y | FORCE LEVEL | STATUS | LOST-PCT | TARGETS |
|---|---|---|---|---|---|---|
| 4 | 4500.0 | 3800.0 | 0.0 | 2 | 1.000 | |
| 5 | 4500.0 | 2700.0 | 0.0 | 2 | 1.000 | 2 |
| 6 | 4600.0 | 1800.0 | 0.0 | 2 | 1.000 | |

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